Single Satellite Footprint (SSF) Definitions (Pathfinder)

(defined for CERES but modified for Pathfinder where ERBE/AVHRR data are used instead)

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Data Product Catalog Listing

Description	Parameter Number	Units	Range	Elements/ Record	Bits/ Elem	Product Code
SSF						
SSF_Header						
1 Product ID		N/A	TBD	1	16	A
2 Day and Time at hour start		N/A	ASCII string	1	216	A
3 Character name of satellite		N/A	ASCII string	1	64	A
4 Character name of CERES instrument		N/A	ASCII string	1	32	A
5 Azimuth scan mode		N/A	ASCII string	1	32	A
6 Character name of high resolution imager instrument		N/A	ASCII string	1	64	A
7 Number of imager channels used		N/A	1 .. 20	1	16	A
8 Central wavelengths of imager channels		μm	0.4 .. 15.0	20	32	A
9 Earth-Sun distance at hour start		AU	0.98 .. 1.02	1	32	A
10 Colatitude of satellite at hour start		deg	0 .. 180	1	32	A
11 Longitude of satellite at hour start		deg	0 .. 360	1	32	A
12 Colatitude of satellite at hour end		deg	0 .. 180	1	32	A
13 Longitude of satellite at hour end		deg	0 .. 360	1	32	A
14 Along-track angle of satellite at hour end		deg	0 .. 340	1	32	A
15 Instrument software version number used to produce IES (SS1.0)		N/A	TBD	1	16	A
16 Cloud properties software version number (SS4-1 - 4.3)		N/A	TBD	1	16	A
17 Convolution of imager with CERES software version number (SS4.4)		N/A	TBD	1	16	A
18 TOA and Surface Estimation software version number (SS4.5 - 4.6)		N/A	TBD	1	16	A
19 Day and Time SSF created		N/A	ASCII string	1	152	A
20 Number of Footprints in SSF product		N/A	0.. 350000	1	32	A
SSF_Record						
Footprint Geometry						
Time and Position						
1 Time of observation	1	day	0 .. 1	1	64	A
2 Radius of satellite from center of Earth at observation	2	km	6000 .. 8000	1	64	A
3 Colatitude of satellite at observation	3	deg	0 .. 180	1	32	A
4 Longitude of satellite at observation	4	deg	0 .. 360	1	32	A
5 Colatitude of Sun at observation	5	deg	0 .. 180	1	32	A
6 Longitude of Sun at observation	6	deg	0 .. 360	1	32	A
7 Colatitude of ERBE FOV at TOA	7	deg	0 .. 180	1	32	A
8 Longitude of ERBE FOV at TOA	8	deg	0 .. 360	1	32	A
9 Colatitude of ERBE FOV at surface	9	deg	0 .. 180	1	32	A
10 Longitude of ERBE FOV at surface	10	deg	0 ..360	1	32	A
11 Scan sample number	11	N/A	1 .. 660	1	16	A
12 Packet number	12	N/A	0 .. 32767	1	16	A
13 Cone angle of ERBE FOV at satellite	13	deg	0 .. 90	1	32	A
14 Clock angle of ERBE FOV at satellite wrt inertial velocity	14	deg	0 .. 360	1	32	A
15 Rate of change of cone angle	15	deg sec^{-1}	-100 .. 100	1	32	A
16 Rate of change of clock angle	16	deg sec^{-1}	-10 .. 10	1	32	A
17 Along-track angle of ERBE FOV at TOA	17	deg	-20 .. 340	1	32	A
18 Cross-track angle of CERES FOV at TOA	18	deg	-90 .. 90	1	32	A
19 X component of satellite inertial velocity	19	km sec^{-1}	-10 .. 10	1	64	A
20 Y component of satellite inertial velocity	20	km sec^{-1}	-10 .. 10	1	64	A
21 Z component of satellite inertial velocity	21	km sec^{-1}	-10 .. 10	1	64	A
ERBE Viewing Angles						
22 ERBE viewing zenith at TOA	22	deg	0 .. 90	1	32	A
23 ERBE solar zenith at TOA	23	deg	0 .. 180	1	32	A

		Units	Range			
24	ERBE relative azimuth at TOA	24	deg	0 .. 360	1	32	A
25	ERBE viewing azimuth at TOA wrt North	25	deg	0 .. 360	1	32	V
Surface_Map Parameters						
26	Altitude of surface above sea level	26	m	-1000 .. 10000	1	32	A
27	Surface type index	27	N/A	1 .. 20	8	16	A
28	Surface type percent coverage	28	N/A	0 .. 100	8	16	A
Scene_Type						
29	ERBE SW ADM type for inversion process	29	N/A	TBD	1	16	A
30	ERBE LW ADM type for inversion process	30	N/A	TBD	1	16	A
31	CERES WN ADM type for inversion process	31	N/A	TBD	1	16	A
Footprint Radiation						
ERBE Filtered Radiances						
32	ERBE TOT filtered radiance, upwards	32	$W\ m^{-2}\ sr^{-1}$	0 .. 700	1	32	I
33	ERBE SW filtered radiance, upwards	33	$W\ m^{-2}\ sr^{-1}$	-10 .. 510	1	32	I
34	CERES WN filtered radiance, upwards	34	$W\ m^{-2}\ sr^{-1}$	0 .. 50	1	32	I
35	Quality flags	35	N/A	see Table TBD	1	32	A
ERBE Unfiltered Radiances						
36	ERBE SW radiance, upwards	36	$W\ m^{-2}\ sr^{-1}$	-10 .. 510	1	32	A
37	ERBE LW radiance, upwards	37	$W\ m^{-2}\ sr^{-1}$	0 .. 200	1	32	A
38	CERES WN radiance, upwards	38	$W\ m^{-2}\ sr^{-1}$	0 .. 50	1	32	A
TOA and Surface Flux						
39	ERBE SW flux at TOA, upwards	39	$W\ m^{-2}$	0 .. 1400	1	32	A
40	ERBE LW flux at TOA, upwards	40	$W\ m^{-2}$	0 .. 500	1	32	A
41	CERES WN flux at TOA, upwards	41	$W\ m^{-2}$	10 .. 400	1	32	A
42	ERBE downward SW surface flux, Model A	42	$W\ m^{-2}$	0 .. 1400	1	32	A
43	ERBE downward LW surface flux, Model A	43	$W\ m^{-2}$	0 .. 700	1	32	A
44	CERES downward WN surface flux, Model A	44	$W\ m^{-2}$	0 .. 250	1	32	A
45	ERBE net SW surface flux, Model A	45	$W\ m^{-2}$	0 .. 1400	1	32	A
46	ERBE net LW surface flux, Model A	46	$W\ m^{-2}$	-250 .. 50	1	32	A
47	ERBE downward SW surface flux, Model B (TBD)	47	$W\ m^{-2}$	0 .. 1400	1	32	A
48	ERBE downward LW surface flux, Model B	48	$W\ m^{-2}$	0 .. 700	1	32	A
49	ERBE net SW surface flux, Model B (TBD)	49	$W\ m^{-2}$	0 .. 1400	1	32	A
50	ERBE net LW surface flux, Model B	50	$W\ m^{-2}$	-250 .. 50	1	32	A
51	ERBE spectral albedo	51	N/A	0 .. 1	6	32	I
52	ERBE broadband surface albedo	52	N/A	0 .. 1	1	32	I
53	ERBE LW surface emissivity	53	N/A	0 .. 1	1	32	I
54	CERES WN surface emissivity	54	N/A	0 .. 1	1	32	I
Full Footprint Area						
55	Number of imager pixels in ERBE FOV	55	N/A	0 .. 9000	1	16	A
56	Imager percent coverage	56	N/A	0 .. 100	1	16	A
57	Precipitable water	57	cm	0.001 .. 10	1	32	A
58	Flag, Source of precipitable water	58	N/A	TBD	1	16	A
59	Shadowed imager pixels percent coverage (TBD)	59	N/A	0 .. 100	1	16	A
60	Imager sunglint percent coverage	60	N/A	0 .. 100	1	16	A
61	Imager-based snow/Ice percent coverage	61	N/A	0 .. 100	1	16	A
62	Imager-based fire percent coverage	62	N/A	0 .. 100	1	16	A
63	Imager-based aerosol percent coverage	63	N/A	0 .. 100	1	16	A
64	Flag, Type of aerosol	64	N/A	0 .. 9999	1	16	A
65	Notes on general procedure	65	N/A	TBD	1	16	A
66	Notes on Cloud Algorithms	66	N/A	TBD	1	16	A
67	Mean imager viewing zenith over ERBE FOV	67	deg	0 .. 90	1	32	A
68	Mean imager relative azimuth over ERBE FOV	68	deg	0 .. 360	1	32	A
Clear Footprint Area						
69	Clear area percent coverage at subpixel resolution	69	N/A	0 .. 100	1	16	A
70	Total aerosol visible optical depth in clear area	70	N/A	0 .. 2	1	32	A
71	Total aerosol effective radius in clear area	71	μm	0 .. 20	1	32	A
72	Imager-based surface skin temperature	72	K	175 .. 375	1	32	I
Cloudy Footprint Area						
Cloud Layer Arrays is Array[2] of:						
73	Cloud layer area percent coverage	73	N/A	0 .. 100	2	16	A
74	Mean cloud visible optical depth for cloud layer	74	N/A	0 .. 400	2	32	A
75	Stddev of visible optical depth for cloud layer	75	N/A	TBD	2	32	A
76	Mean logarithm of cloud visible optical depth for cloud layer	76	N/A	0 .. 6	2	32	A
77	Stddev of logarithm of visible optical depth for cloud layer	77	N/A	TBD	2	32	A
78	Mean cloud infrared emissivity for cloud layer	78	N/A	0 .. 1	2	32	A
79	Stddev of cloud infrared emissivity for cloud layer	79	N/A	TBD	2	32	A
80	Mean liquid water path for cloud layer	80	$g\ m^{-2}$	TBD	2	32	A
81	Stddev of liquid water path for cloud layer	81	$g\ m^{-2}$	TBD	2	32	V
82	Mean ice water path for cloud layer	82	$g\ m^{-2}$	TBD	2	32	A
83	Stddev of ice water path for cloud layer	83	$g\ m^{-2}$	TBD	2	32	V
84	Mean cloud top pressure for cloud layer	84	hPa	0 .. 1100	2	32	A
85	Stddev of cloud top pressure for cloud layer	85	hPa	TBD	2	32	V

#	Description	#	Units	Range	Dim	Bits	Type
86	Mean cloud effective pressure for cloud layer	86	hPa	0 .. 1100	2	32	A
87	Stddev of cloud effective pressure for cloud layer	87	hPa	TBD	2	32	A
88	Mean cloud effective temperature for cloud layer	88	K	100 .. 350	2	32	A
89	Stddev of cloud effective temperature for cloud layer	89	K	TBD	2	32	A
90	Mean cloud effective height for cloud layer	90	km	0 .. 20	2	32	A
91	Stddev of cloud effective height for cloud layer	91	km	TBD	2	32	V
92	Mean cloud base pressure for cloud layer	92	hPa	0 .. 1100	2	32	A
93	Stddev of cloud base pressure for cloud layer	93	hPa	TBD	2	32	V
94	Mean water particle radius for cloud layer	94	µm	TBD	2	32	A
95	Stddev of water particle radius for cloud layer	95	µm	TBD	2	32	A
96	Mean ice particle effective diameter for cloud layer	96	µm	TBD	2	32	A
97	Stddev of ice particle effective diameter for cloud layer	97	µm	TBD	2	32	A
98	Mean cloud particle phase for cloud layer	98	N/A	1 .. 2	2	32	A
99	Stddev of cloud particle phase for cloud layer	99	N/A	0 .. 1	2	32	V
100	Mean vertical aspect ratio for cloud layer (TBD)	100	N/A	0 .. 20	2	32	A
101	Stddev of vertical aspect ratio for cloud layer (TBD)	101	N/A	TBD	2	32	V
102	Percentiles of visible optical depth for cloud layer	102	N/A	TBD	2 x 13	32	I
103	Percentiles of IR emissivity for cloud layer	103	N/A	TBD	2 x 13	32	I

Overlap Footprint Area

#	Description	#	Units	Range	Dim	Bits	Type
104	Overlap condition weighted area percentage	104	N/A	0 .. 100	4	16	A

Footprint Imager Radiance Statistics

#	Description	#	Units	Range	Dim	Bits	Type
105	Imager channel central wavelength	105	µm	0.4 .. 15.0	5	32	I
106	Clear area percent coverage at imager resolution	106	N/A	0 .. 100	1	16	I
107	Overcast cloud area percent coverage at imager resolution	107	N/A	0 .. 100	1	16	I
108	Mean of imager radiances over clear area	108	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I
109	Stddev of imager radiances over clear area	109	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I
110	Mean of imager radiances over overcast cloud area	110	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I
111	Stddev of imager radiances over overcast cloud area	111	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I
112	Mean of imager radiances over full ERBE FOV	112	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I
113	Stddev of imager radiances over full ERBE FOV	113	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I
114	5th percentile of imager radiances over full ERBE FOV	114	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I
115	95th percentile of imager radiances over full ERBE FOV	115	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I
116	Mean of imager radiances over cloud layer 1 (no overlap)	116	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I
117	Stddev of imager radiances over cloud layer 1 (no overlap)	117	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I
118	Mean of imager radiances over cloud layer 2 (no overlap)	118	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I
119	Stddev of imager radiances over cloud layer 2 (no overlap)	119	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I
120	Mean of imager radiances over cloud layer 1 and 2 overlap	120	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I
121	Stddev of imager radiances over cloud layer 1 and 2 overlap	121	$W\ m^{-2}\ sr^{-1}\ \mu m^{-1}$ TBD		5	32	I

Total Meta Bits/File:	1520
Total Data Bits/Record:	**8528**
Total Records/File:	~30,000
Total Data Bits/File:	**2.56E8**

Total MegaBytes / Hour	~32
Total GigaBytes / Day	0.77

SSF General Definitions/Assumptions

1. The product codes used are defined as follows: A - Archival, data of interest to general user community; I - Internal use, data required by other subsystems or for reprocessing; V - Validation data. The order in which the codes were described (A,I,V) is also the order of precedence. Initially, all data will be saved in unpacked flat files. In the future, the flat file will be converted to HDF and deleted after processing. To reprocess, the HDF file will get converted back to a flat file.
2. Field of View (FOV) and footprint may be used interchangeably. In the following paragraphs, FOV will be used.
3. Satellite and spacecraft may be used interchangeably. In the following paragraphs, satellite will be used.
4. The SSF will only contain those Fields Of View (FOV) for which there is adequate associated imager data (ATBD 4.4) and a correct view vector.
5. The ranges stated for each parameter are absolute. It is expected that they will never be exceeded.
6. The IES will contain only earth viewing FOVs for which there are valid Surface Colatitude and Longitude.
7. The IES may contain data for which 1 or more radiance values are flagged as bad.
8. The IES will contain all radiance values which make it through the count conversion routine. Any values which are suspect, for any reason, should be flagged as bad. The Instrument subsystem need not do any range checking of the radiance values - this will be handled by Inversion.
9. In those cases where a variable value can not be computed and has no flag associated with it, the variable will be set to the standard ERBE default value. Similarly, any non-flagged variable value which is suspect will be replaced by the appropriate ERBE default value. Values which have corresponding flags need not be set to the ERBE default value when the data is suspect. The ERBE default value is the largest number supported by the data type.
10. The Point Spread Function (PSF) centroid within the FOV at Top Of Atmosphere (TOA) is referred to as the target point. Target point has an ERBE heritage. The PSF will change based on the rate of change of cone angle. Currently, two PSFs are defined; a static PSF and a PSF for the nominal elevation scan rate of approximately 63 degrees/second. FOVs sampled at an elevation scan rate of approximately 249 degrees/second will be discarded from the SSF.
11. All colatitude and longitude values are given as geocentric coordinates.
12. For the CERES instrument in a Fixed Azimuth Plane Scan (FAPS) mode and assuming a normal or a short elevation scan, a maximum of 246546 FOVs per hour are expected for TRMM, and 221455 FOVs per hour for are expected for EOS. This is based on a TRMM estimate of 226 FOVs per half scan and an EOS estimate of 203 FOVs per half scan (NOTE 1). These are only estimates. The actual number of FOVs per file will vary based on the type of scan and imager data availability. In most cases, the number of FOVs will be less than stated because the FOVs outside the imager data swath will not be recorded on the SSF. For Pathfinder, only ERBE data are used; ERBE collected data in crosstrack mode at a rate of approximately 30,000 FOV's/hour.
13. An hour file contains all the FOVs collected within the hour, but the FOVs are ordered based on along-track angle. The along-track angle of the satellite at the beginning of an hour is

defined to be 0. The along-track angle of the satellite at the end of the hour is recorded on the header and corresponds to the along-track angle of the satellite at the beginning of the next hour. FOVs with negative along-track angles and super along-track angles may exist for every hour. Super along-track angles are defined as along-track angles which exceed the along-track angle of the satellite at hour end.

14. The SSF will be created in two stages. During the first stage, only the data copied from the IES and the data produced by the clouds subsystem (ATBD 4.1 - 4.4) will reside in an interim SSF.   During the second stage, the interim SSF will be read and the radiances will be inverted (ATBD 4.5) and surface estimates (ATBD 4.6) will be computed.

15. The SSF must have restart capability.

16. Most parameters generated for the SSF by Subsystem 4.4 are based on data computed at an imager pixel level or imager pixel subgrid level by Subsystems 4.1-4.3. Subsystem 4.4 uses a PSF weighting over the ERBE FOV to compute most parameters. Those parameters which are not PSF-weighted will be denoted as such.

17. The TRMM subgrid is equal to the imager grid at 2 km. The MODIS subgrid is 250 m and the MODIS imager grid is 1 km. The subgrid for Pathfinder is based on AVHRR GAC (4-km) data. For a better understanding of how this affects SSF parameters, refer to Note 1.

18. For the purposes of the document, a clear imager pixel is defined as an imager pixel with a derived cloud fraction of 0.0. Similarly, an overcast imager pixel is defined as an imager pixel with a derived cloud fraction of 1.0.

19. Imager pixel resolution means that each imager pixel is equally weighted within the angular bin. A parameter computed at imager pixel resolution takes into account individual imager pixel values, the imager pixel's weight within the angular bin, and the angular bin's weight within the FOV. Imager pixel resolution and imager resolution may be used interchangeably within this document.

20. Subpixel resolution means that each subpixel in the subgrid is equally weighted within the imager pixel. The imager pixels within the angular bin are also equally weighted. A parameter computed at subpixel resolution takes into account the subpixel values within the imager pixel, the imager pixel's weight within the angular bin, and the angular bin's weight within the FOV.

21. Bin resolution means that all the imager pixel values within the angular bin have been combined in such a way that there is only a single value for the entire angular bin.

22. Upwelling fluxes are defined to be positive. Downwelling fluxes are defined to be positive. Net flux is defined as downwelling flux minus upwelling flux. (Kratz, 11/96)

23. Where it is critical that the user understand that a parameter has been created from imager pixel data, imager or imager-based have been added to the parameter name. This is done for several reasons. In some cases, it eliminates confusion between similar parameters which might be derived from or for the ERBE FOV. In other cases, it is to distinguish between a similar parameter on the SSF that is derived independently from another source.

Differences since October 1996

- Number of Footprints in SSF product range increased to accommodate elevation scans which behave like nadir scan
- Along-track angle range limited to 340 degrees to avoid confusion
- Azimuth scan mode parameter moved within SSF Header
- Colatitude and Longitude of satellite at beginning and end of hour added to SSF Header
- Along-track angle of satellite at end of hour added to SSF Header
- Cloud category references changed to Cloud layer
- Sunglint, Snow/Ice, Fire, and Aerosol percent coverages moved to Full Footprint Area due to change in definition initiated by Bryan Baum
- Flag, Type of aerosol moved to Full Footprint Area
- Time of observation range changed from -0.01.. 1.01 to 0 .. 1.
- Cloud bottom pressure changed to cloud base pressure at Bryan Baum's request
- Shadowed pixels percent coverage, snow/ice percent coverage, fire percent coverage, and aerosol percent coverage have been changed to shadowed imager pixels percent coverage, imager-based snow/ice percent coverage, imager-based fire percent coverage, and imager-based aerosol percent coverage.
- Sunglint percent coverage has been changed to imager sunglint percent coverage.
- SSF-69, Clear area percent coverage, renamed to Clear are percent coverage at subpixel resolution.

SSF Header Definition

(defined for CERES but modified for Pathfinder where ERBE/AVHRR data are used)

1. Product ID [range TBD]

The Product ID is a number which identifies this file as an SSF data product of a given format. The Product ID will be written in the header by the software which created the data file and should be verified by all software intending to read an SSF data product. The Product ID will be modified every time the SSF data structure or SSF header structure is changed, therefore guarding against reading the binary data incorrectly. For Pathfinder, the Product ID is set to a value of 110.

2. Day and Time at hour start

The day and time at hour start is the Coordinated Universal Time (UTC). Day and Time come from the level 0 file secondary header. Day and time at hour start are stored as a 27 byte ASCII string of the form YYYY-MM-DDThh:mm:ss.dddddZ [Example: 2002-02-23T14:04:57.987654Z]. This directly corresponds to the CCSDS ASCII Time Code A returned by the toolkit call which converts spacecraft clock time to UTC time (SDP Toolkit Users Guide for the ECS Project). For more information about time, see CERES software bulletin 95-10, dated August 25, 1995 or the SDP Toolkit Users Guide for the ECS Project section on Time and Date Conversion Tools. This variable is derived via toolkit call from the julian day and time located on the IES header.

3. Character name of satellite

The character name of the satellite is the name of the platform from which the data set was obtained. Valid satellite names are TRMM, EOS-AM1, and EOS-PM1 etc. The character name of satellite is an 8 byte ASCII string. The satellite name begins in the left most position and any remaining bytes are filled with blank spaces. This string is based on the information received in the level 0 file. This variable is copied from the IES. For Pathfinder, the character name is set to "NOAA-9".

4. Character name of ERBE/CERES instrument

The character name of the CERES instrument is the acronym typically associated with a particular instrument. Valid CERES instrument names are PFM, FM1, and FM2. The character name of CERES instrument is a 4 byte ASCII string. The instrument name begins in the left most position and any remaining bytes are filled with blank spaces. This string is based on the level 0 file unique instrument identifier. This variable may be copied from the IES or derived from a CERES instrument identifier found in the IES header. For Pathfinder, the instrument name is set to "ERBE".

5. Azimuth scan mode

The azimuth scan mode indicates whether or not the azimuth is rotating during this hour of data. Valid scan mode values are RAPS, FAPS, and COMB. RAPS is a rotating azimuth plane scan, FAPS is a fixed azimuth plane scan, and COMB is a combination of RAPS and FAPS. The azimuth plane scan is a 4 character string. It can be copied from the IES when the IES file consists of entirely of either FAPS or RAPS data, but must be determined and written by Subsystem 4.4

when the IES data is a combination. For Pathfinder, the scan mode is always FAPS.

6. Character name of high resolution imager instrument

The character name of the high resolution imager instrument is the name of the high resolution imager aboard the same satellite as the named ERBE instrument. For Pathfinder, the imager is AVHRR. The imager pixels (see SSF-26)s from this high resolution imager were convolved with the ERBE/CERES FOV to determine cloud properties for the ERBE/CERES FOV. Valid high resolution imager names are VIRS, MODIS-AM, and MODIS-PM. The character name of the high resolution imager instrument is an 8 byte ASCII string. The imager name begins in the left most position and any remaining bytes are filled with blank spaces. This variable may be copied from cookie dough or may be generated by looking up the imager mounted on the specified satellite. In either case, Subsystem 4.4 places the imager name on the SSF. For Pathfinder, the imager is set to "ERBE" (we need to change the name to "AVHRR").

7. Number of imager channels used [1 to 20]

The number of imager channels used indicates the number of narrowband, high resolution imager channels subsystems 4.1-4.3 used for determining cloud and clear-sky properties. For Pathfinder, we are using 4 of the 5 AVHRR channels (all but the 0.83-μm channel, which isn't available on VIRS). For TRMM, all 5 VIRS channels will be used. For EOS, approximately 17 MODIS channels are expected to be used. The actual wavelengths of the channels used are recorded in the array that follows. The number of imager channels used is a 16 bit integer, ranges from 1 to 20, and is copied from cookie dough. For Pathfinder, the number of imager channels is set to "20".

8. Central wavelengths of imager channels [0.4 to 15.0 μm]

The central wavelengths of the imager channels are the central wavelengths of the narrowband, high resolution imager channels used by subsystems 4.1-4.3 to determine cloud and clear-sky properties. An array of 20 single precision real values has been reserved for these values which range from 0.4 to 15.0 μm. The central wavelengths of imager channels are based on the imager used and are copied from cookiedough. For Pathfinder, the first five channels contain the central wavelengths for AVHRR.

9. Earth-Sun distance at hour start [0.98 to 1.02 AU]

The Earth-Sun distance is the approximate distance from the Earth to the Sun in astronomical units (AU) at the beginning of the hour. It is a 32 bit floating point number.

10. Colatitude of satellite at hour start [0.0 to 180.0 deg]

The colatitude of satellite at hour start is the colatitude of the satellite in the Earth equator, Greenwich meridian coordinate system at the beginning of the hour. It is the same as the colatitude of satellite at hour end written on the previous hour's SSF. It is a 32 bit floating point number. This variable is copied from the IES. NOTE: For Pathfinder, the satellite colatitude at hour start is set to 0.

11. Longitude of satellite at hour start [0.0 to 360.0 deg]

The longitude of satellite at hour start is the longitude of the satellite in the Earth equator, Greenwich meridian coordinate system. It is the same as the longitude of satellite at hour end written on the previous hour's SSF. It is a 32 bit floating point number. This variable is copied from the IES. NOTE: For Pathfinder, the satellite longitude at hour start is set to 0.

12. Colatitude of satellite at hour end [0.0 to 180.0 deg]

The colatitude of satellite at hour end is the colatitude of the satellite in the Earth equator, Greenwich meridian coordinate system at the end of the hour. It corresponds to the colatitude of satellite at hour start written on the next hour's SSF. It is a 32 bit floating point number. This variable is copied from the IES. NOTE: For Pathfinder, the satellite colatitude at hour end is set to 0.

13. Longitude of satellite at hour end [0.0 to 360.0 deg]

The longitude of satellite at hour end is the longitude of the satellite in the Earth equator, Greenwich meridian coordinate system at the end of the hour. It corresponds to the longitude of satellite at hour start written on the next hour's SSF. It is a 32 bit floating point number. This variable is copied from the IES. NOTE: For Pathfinder, the satellite longitude at hour end is set to 0.

14. Along-track angle of satellite at hour end [0.0 to 340.0 deg]

The along-track angle of satellite at hour end is the angle about the center of the earth, through which the satellite has traveled since the start of the hour. We define a vector from the center of the Earth to the satellite at the start of the hour. We define another vector from the center of the Earth to the satellite at the end of the hour. The along-track angle is the angle, at the center of the earth, from the satellite vector at hour start to the satellite vector at hour end. The along-track angle of satellite at hour start is, by definition, 0.0. The position of the satellite at hour end always corresponds to an along-track angle of 0.0 degrees in the next hour. The along-track angle is measured along the arc traveled by the spacecraft. The along-track angle of satellite at hour end is a 32 bit floating point number. This variable is copied from the IES. For Pathfinder, the along-track angle of satellite at hour end is set to 0.

15. Instrument software version number used to produce IES (SS1.0) [range TBD]

The Instrument software version number used to produce IES is the version of the software that subsystem 1.0 ran to produced the IES which subsystem 4.4 convolved with the CERES data. The version number is stored as a 16 bit integer. For Pathfinder, the version number is set to 1.

16. Cloud properties software version number (SS4.1 - 4.3) [range TBD]

The Cloud properties software version number is the version of the software that subsystems 4.1-4.3 ran to produce the cookiedough which subsystem 4.4 convolved with the CERES data. The version number is stored as a 16 bit integer and for Pathfinder is set to 2.

17. Convolution of imager with CERES software version number (SS4.4) [range TBD]

The Convolution of imager with CERES software version number is the version of the software that subsystem 4.4 ran to convolve the IES and cookiedough to produce the interim SSF. The version number is stored as a 16 bit integer. It is determined and written by subsystem 4.4. For Pathfinder, the version number is set to 2.

18. TOA and Surface Estimation software version number (SS4.5 - 4.6) [range TBD]

The TOA and Surface Estimation software version number is the version of software that subsystems 4.5-4.6 ran using the interim SSF as input to produce the archival SSF. Top of Atmosphere (TOA) is defined to be 30 km above the WGS84 ellipsoidal model of the earth. The version number is stored as a 16 bit integer. It is determined and written by subsystems 4.5-4.6 and will contain a CERES default (see SSF-26) value on the interim SSF data product. For Pathfinder, the version number is set to CERES default (which is 32767).

19. Day and Time SSF created

The day and time SSF created is the day and time this instance of an SSF was created. The date is stored as a 19 byte ASCII string of the form YYYY-MM-DDThh:mm:ss [Example: 2002-02-23T14:04:57]. Day and time are determined and written by the creating subsystem, either 4.4 or 4.5-4.6.

20. Number of Footprints in SSF product [0 to 350000]

The number of Footprints in SSF product is a count of the ERBE FOVs written to this file. The number of footprints in the SSF product is written by the subsystem which generated the SSF.

SSF(I) Variable Definition

SSF-1   Time of Observation [0.0 to 1.0]

The time of observation is the fractional part of the day in Julian time. Note that the julian day changes at noon rather than midnight. CERES software bulletin 96-07 states that the SSF will contain all the data accumulated during that hour, regardless of along-track angle. For more information about time, see CERES software bulletin 95-10, dated August 25, 1995. Time of observation is a 64 bit floating point number.

SSF-2   Radius of satellite from center of earth at observation [6000.0 to 8000.0 km]

The radius of satellite from the center of earth is the distance, in kilometers, from the satellite to the center of the Earth. It is a 64 bit floating point number. This variable is valid for the entire scan line.

SSF-3   Colatitude of satellite at observation [0.0 to 180.0 degrees]

The colatitude of satellite at observation is the colatitude of the satellite in the Earth equator, Greenwich meridian coordinate system. The colatitude of the North Pole is 0 degrees. Correspondingly, the colatitude of the South Pole is 180 degrees. It is a 32 bit floating point number.

SSF-4   Longitude of satellite at observation [0.0 to 360.0 degrees]

The longitude of satellite at observation is the longitude of the satellite in the Earth equator, Greenwich meridian coordinate system. It is a 32 bit floating point number.

SSF-5   Colatitude of Sun at observation [0.0 to 180.0 degrees]

The colatitude of sun for the ERBE scan line is in the Earth equator, Greenwich meridian coordinate system. It is a 32 bit floating point number.

SSF-6   Longitude of Sun at observation [0.0 to 360.0 degrees]

The longitude of sun for the ERBE scan line is in the Earth equator, Greenwich meridian coordinate system. It is a 32 bit floating point number.

SSF-7   Colatitude of ERBE FOV at TOA [0.0 to 180.0 degrees]

The colatitude of ERBE FOV at TOA is the colatitude, in the Earth equator, Greenwich meridian coordinate system, of the target point. The target point is the point at which the Point Spread Function (PSF) (see SSF-26) centroid falls upon the ellipsoidal Top Of the Atmosphere (TOA). The Colatitude of CERES FOV at TOA is a 32 bit floating point number.

SSF-8   Longitude of ERBE FOV at TOA [0.0 to 360.0 degrees]

The longitude of ERBE FOV at TOA is the longitude, in the Earth equator, Greenwich meridian coordinate system, of the target point (see SSF-7) using the CERES_TOA model. It is a 32 bit floating point number.

SSF-9   Colatitude of ERBE FOV at surface [0.0 to 180.0 degrees]

The colatitude of ERBE FOV at surface is the colatitude, in the Earth equator, Greenwich meridian coordinate system, at which the Point Spread Function (PSF) (see SSF-26) centroid falls

on the Earth using the WGS84 Earth model. The Colatitude of the ERBE FOV at surface is a 32 bit floating point number. For Pathfinder, the colatitude at the surface is set to the TOA colatitude.

SSF-10   Longitude of ERBE FOV at surface [0.0 to 360.0 degrees]

The longitude of ERBE FOV at surface is the longitude, in the Earth equator, Greenwich meridian coordinate system, at which the Point Spread Function (PSF) (see SSF-26) centroid falls on the Earth using the WGS84 Earth model. It is a floating point number ranging from 0 to 360 degrees. For Pathfinder, the longitude at the surface is set to the TOA longitude.

SSF-11   Scan sample number [1 to 660]

The scan sample number defines the order in which the ERBE FOVs (see SSF-26) were collected by the instrument during a single scan cycle. Every scan cycle begins with sample 1 and ends with sample 660. The scan sample number is a 16 bit integer. For Pathfinder, the sample number is simulated based on TISA requirements for sharpening.

SSF-12   Packet number [0 to 32767]

This number is irrelevant for Pathfinder, but is necessary for CERES processing.

SSF-13   Cone angle of ERBE FOV at satellite [0.0 to 90.0 degrees]

The cone angle of ERBE FOV at satellite is the angle between a vector from the satellite to the center of the Earth and a vector from the satellite to the target point (see SSF-7).   Cone angle is a 32 bit floating point number.   For Pathfinder, the value is set to a CERES default (see SSF-26).

SSF-14   Clock angle of ERBE FOV at satellite wrt inertial velocity [0.0 to 360.0 degrees]

The clock angle of ERBE FOV at satellite wrt inertial velocity is the angle between a vector, perpendicular to the radius vector, in the direction of inertial velocity and a vector, perpendicular to the radius vector, in the direction of the target point (see SSF-7). The angle is based on a right-handed coordinate system where x is in the direction of inertial velocity and z is toward the center of the earth. When the clock angle is 270 degrees, the target point is on the same side of the orbit as the orbital angular momentum vector. Clock angle is a 32 bit floating point number and is set to a CERES default (see SSF-26) for Pathfinder.

SSF-15   Rate of change of cone angle [-100.0 to 100.0 degrees/second]

The rate of change of the cone angle is the angular velocity, in degrees per second, at which the cone angle is increasing.   The cone angle rate of change is negative when sweeping toward nadir, positive when sweeping away from nadir, and zero when the cone angle is constant. The cone angle rate is determined based on scan angle position at each CERES FOV (see SSF-26) and has a precision of 0.55 deg/sec (1 raw count = 0.55 deg/sec). Therefore, cone angle rate changes of 0.55 between CERES FOVs and cone angle rate changes of 1.1 over several CERES FOVs are not uncommon. The cone angle rate of change is a 32 bit floating point number. This variable is copied from the IES. This parameter is not computed for Pathfinder but is set to +/- 63.5 degrees.

SSF-16   Rate of change of clock angle [-10.0 to 10.0 degrees/second]

The rate of change of the clock angle is the angular velocity, in degrees per second, at which the clock angle is increasing. When the instrument is operating in a Fixed Azimuth Plane Scan

(FAPS) mode, the clock angle rate of change will always be zero. Like the cone angle rate, the clock angle rate is also expected to vary between CERES FOVs (see SSF-26) but the effects are predicted to be much greater, about 10% of the average rate value. The clock angle rate of change is a 32 bit floating point number. This variable is set to CERES default for Pathfinder.

SSF-17   Along-track angle of ERBE FOV at TOA [-20.0 to 360.0 degrees]

The along-track angle of ERBE FOV at TOA is the target point's [see SSF-7] in-orbit-plane angle. We define a vector from the center of the Earth to the satellite at the start of the hour. Let us refer to this vector as the satellite vector. We define another vector from the center of the Earth to the target point. The along-track angle is the angle, at the center of the earth, from the satellite vector to the projection of the target point onto the orbit plane. The along-track angle is measured along the arc traveled by the spacecraft and can exceed 180 degrees. For an illustration see the ATBD for Subsystem 4.4. The angle is based on a right handed coordinate system with the origin at the center of the earth. The Z axis is along the angular momentum vector, and the X axis is the satellite vector.

ERBE FOVs (see SSF-26) on the SSF are in order of increasing along-track angle. The along-track angle is a 32 bit floating point number.

SSF-18   Cross-track angle of ERBE FOV at TOA [-90.0 to 90.0 degrees]

The cross-track angle of the ERBE FOV at TOA is the target point's [see SSF-7] out-of-orbit-plane angle. The cross-track angle is the angle, at the center of the Earth, between the target point vector and its projection onto the orbit plane [see SSF-17]. The angle is positive if the target point is on the same side of the orbit as the angular momentum vector. Otherwise, it is negative. The cross-track angle is a 32 bit floating point number.

SSF-19   X component of satellite inertial velocity [-10.0 to 10.0 km/sec]

The X component of satellite inertial velocity is inertial velocity of the satellite along the x-axis in the Earth equator, Greenwich meridian coordinate system. It is a 64 bit floating point number.

SSF-20   Y component of satellite inertial velocity [-10.0 to 10.0 km/sec]

The Y component of satellite inertial velocity is inertial velocity of the satellite along the y-axis in the Earth equator, Greenwich meridian coordinate system. It is a 64 bit floating point number ranging.

SSF-21   Z component of satellite inertial velocity [-10.0 to 10.0 km/sec]

The Z component of satellite inertial velocity is inertial velocity of the satellite along the z-axis in the Earth equator, Greenwich meridian coordinate system. It is a 64 bit floating point number.

SSF-22   ERBE viewing zenith at TOA [0.0 to 90.0 degrees]

The ERBE viewing zenith at TOA is the angle between the vector from the center of the Earth through the target point (see SSF-7) and a vector from the target point to the satellite. It is a 32 bit floating point number.

SSF-23   ERBE solar zenith at TOA [0.0 to 180.0 degrees]

The ERBE solar zenith at TOA is the angle between the vector from the center of the Earth through the target point (see SSF-7) and a vector from the target point to the sun. It is a 32 bit floating point number.

SSF-24   ERBE relative azimuth at TOA [0.0 to 360.0 degrees]

The ERBE relative azimuth at TOA is the azimuth angle of the satellite at the target point (see SSF-7) relative to the solar plane. The azimuth is measured clockwise in the local horizon plane so that the azimuth of the sun is always 180 degrees. If the target point is north of the sun on the same meridian, then an azimuth of 90 degrees would imply the satellite is east of the target area. The ERBE relative azimuth at TOA is a 32 bit floating point number.

SSF-25   ERBE viewing azimuth at TOA wrt North [0.0 to 360.0 degrees]

The ERBE viewing azimuth at TOA wrt North is the azimuth angle of the satellite at the target point (see SSF-7) relative to North. The angle is based on a right handed coordinate system with the origin at the target point, the Z axis along the radius vector, and the X axis going North.   It is a 32 bit floating point number.

SSF-26   Mean altitude of surface above sea level [-1000.0 to 10000.0 m]

The mean altitude of surface above sea level is a PSF-weighted bin-average of valid imager pixel altitudes which fall within the current ERBE FOV. An imager pixel is an imager observation point. For Pathfinder the imager pixel resolution is approximately a 4 km grid. A ERBE footprint or Field of View (FOV) is a ERBE observation point. An ERBE FOV is defined by the ERBE point spread function (PSF) which gives the appropriate weighting of the field with respect to the optical axis. A full discussion of the PSF and its development are given in Smith (1994). The discrete imager pixels will not be uniformly spaced over the ERBE FOV so that we must average over smaller sections of the ERBE FOV and then integrate. These smaller sections of the ERBE FOV are defined in angular space and are, therefore, referred to as angular bins. ATBD Subsystem 4.4 (Green 1996) defines the integration over the ERBE FOV and defines the rectangular, angular grid. Each angular bin is assigned a weight based on the ERBE PSF. The sum of all the angular bin weights over the ERBE FOV is slightly greater than 95% energy. A bin-average is computed by simply averaging all the non CERES default parameter values associated with the imager pixels which fall within the angular bin to compute a single value for that bin. A CERES default value is the largest number supported by that data type. CERES default values are used when a parameter value could not be computed or was considered suspect and the parameter does not have a flag associated with it. These bin-averaged parameter values are then averaged over the ERBE FOV using each angular bin's respective PSF weighting to compute a PSF-weighted bin-average.

Given an imager pixel's colatitude and longitude, Subsystem 4.1-4.3 retrieves the imager pixel's surface altitude from SURFMAP. If there are imager pixels with valid altitude values within the corresponding ERBE FOV, Subsystem 4.4 computes the PSF-weighted bin-average altitude, otherwise the mean altitude is set to CERES default. For every angular bin, the imager pixel altitudes are averaged together and the mean altitude is computed at a bin resolution. The mean altitude is a 32 bit floating point number and is placed on the SSF by Subsystem 4.4.

SSF-27   Surface type index [0 to 20]

    The surface type index is a list of the 8 most prominent surface types within the ERBE FOV (see SSF-26). SSF-28 contains the corresponding area coverages. The possible surface types are:

        1 - Evergreen Needleleaf Forest
        2 - Evergreen Broadleaf Forest
        3 - Deciduous Needleleaf Forest
        4 - Deciduous Broadleaf Forest
        5 - Mixed Forest
        6 - Closed Shrublands
        7 - Open Shrublands
        8 - Woody Savannas
        9 - Savannas
       10 - Grasslands
       11- Permanent Wetlands
       12 - Croplands
       13 - Urban and Built-up
       14 - Cropland Mosaics
       15 - Snow and Ice
       16 - Bare Soil and Rocks
       17 - Water Bodies
       18 - Tundra
       19 - Fresh Snow
       20 - Sea Ice

    Of these possible 20 surface types, types 1 - 17 correspond to those defined by IGBP. The 8 surface type indices are ordered on area coverage with the largest being first. If there are fewer than 8 surface types falling within an ERBE FOV, all the remaining indice locations will be filled with the CERES default (see SSF-26) value. Of the last 3 additional surface types defined for CERES (and Pathfinder), fresh snow, number 19, and sea ice, number 20, are not permanent surface types. They are brought in weekly, and eventually expect to be brought in daily. The IGBP surface type snow and ice, number 15, is permanent snow and ice. It is not updated. None of these snow and ice surface types are related to the imager-based snow/ice percent coverage defined in SSF-61. Each of the indices is a 16 bit integer and is placed on the SSF by Subsystem 4.4.

SSF-28   Surface type percent coverage [0 to 100 percent]

    The surface type percent coverage contains the integer percentage of the PSF-weighted ERBE FOV (see SSF-26) coverage of the corresponding surface type at imager pixel resolution. Because the surface types are arranged by prominence, the percent coverage will always be decreasing. If there are fewer than 8 surface types denoted, the remaining percent coverage are set to the CERES default (see SSF-26). If there are 8 or fewer surface types present within the ERBE FOV, the non CERES default percent of surface coverage must sum to 100. When there are more than 8 surface types present within a ERBE FOV, the sum of percent coverage will be less than 100. The Surface type percent coverage is a 16 bit integer placed on the SSF by Subsystem 4.4.

SSF-29   ERBE SW ADM type for inversion process [range TBD]

    The ERBE SW ADM type for inversion process is the combined scene identified by the

imager pixels (see SSF-26) within the ERBE FOV (see SSF-26). Initially, the ERBE production ADMs with 12 scene types will be used for the inversion from radiance to flux at the TOA (see SSF-7). Later, the new CERES ADMs with 200 SW scene types will be used (ATBD 4.5). Both sets of ADMs will use the value of 0 to denote unknown scene. The 12 ERBE scene types are based on cloud amount, and 5 geotypes. Cloud amount is 1 - clear (SSF-69) and geotypes are from the 20 surface types (SSF-27).

> Land: surface types 1-6, 8-14, 18
> Water: surface types 17
> Snow: surface types 15, 19, 20
> Desert: surface types 7, 16

If all surface type indices are set to CERES default (see SSF-26) or if the total surface area sums to zero percent, then the ERBE geotype and, consequently, the ERBE ADM type are set to CERES default.

To determine the ERBE geotype for the ERBE FOV, the following algorithm is used:

> If %desert > 50 then fov_geotype = DESERT
> Else if %snow > 50 then fov_geotype = SNOW
> Else if %water > 67 then fov_geotype = WATER
> Else if (%land + %desert + %snow) > 67 then fov_geotype = LAND
> Else fov_geotype = COAST

However, if the non-default sum of the surface type percent coverages exceeds 101 or is less than or equal to 90, then the ERBE geotype and, consequently, the ERBE ADM type are set to unknown.

The ERBE FOV cloud percentage is determined by subtracting the clear percent coverage at the subpixel resolution (SSF-69) from 100. However, if by some quirk, the clear percent coverage at subpixel resolution is set to CERES default, the ERBE ADM type is also set to CERES default. The amount of cloud coverage is based on the following mapping:

> If 0 <= cloud percentage < = 5 then CLEAR
> Else if 5 < cloud percentage <= 50 then PARTLY CLOUDY
> Else if 50 < cloud percentage <= 95 then MOSTLY CLOUDY
> Else if 95 < cloud percentage <= 100 then OVERCAST

.

The appropriate ERBE ADM type is then selected based on the ERBE FOV geotype and cloud cover. The ERBE ADM types are as follows:

> 0 - unknown
> 1 - clear water
> 2 - clear land
> 3 - clear snow
> 4 - clear desert
> 5 - clear land-water mix
> 6 - partly cloudy water
> 7 - partly cloudy land or desert
> 8 - partly cloudy land-water mix
> 9 - mostly cloudy water
> 10 - mostly cloudy land or desert

> 11 - mostly cloudy land-water mix
> 12 - overcast all land types; partly cloudy snow; mostly cloudy snow

This 16 bit integer variable is placed on the SSF by Subsystem 4.5.

SSF-30   ERBE LW ADM type for inversion process [range TBD]

The ERBE LW ADM type for inversion process is the combined scene identified by the imager pixels (see SSF-26) within the ERBE FOV (see SSF-26). Initially, the ERBE production ADMs with 12 scene types will be used for the inversion from radiance to flux at the TOA (see SSF-7). For ERBE ADMs the scene type for LW is the same as for SW (see SSF-29). Later, the new CERES ADMs with 600 LW scene types will be used (ATBD-4.5). This 16 bit integer variable is placed on the SSF by Subsystem 4.5.

SSF-31   CERES WN ADM type for inversion process [range TBD]

The CERES WN ADM type for inversion process is the combined scene identified by the imager pixels (see SSF-26) within the CERES FOV(see SSF-26). Initially, the window channel scene type will be the same as the longwave scene type (SSF-30). Later, the new CERES ADMs with 600 scene types will be used. The 600 scene types for the window channel may be the same or different than the longwave scene types. This 16 bit integer variable is placed on the SSF by Subsystem 4.5. Since ERBE had no window channel, this parameter is set to the LW ADM value in Pathfinder.

SSF-32   ERBE TOT filtered radiance, upwards [0 to 700 W m^{-2} sr^{-1}]

The ERBE TOT filtered radiance, upwards is the total channel measurement at satellite altitude. If this value is suspect, for any reason, the corresponding bits in the quality flag (SSF-35) will be set to non-zero. This variable is a 32 bit floating point number.

SSF-33   ERBE SW filtered radiance, upwards [-10.0 to 510.0 W m^{-2} sr^{-1}]

The ERBE SW filtered radiance, upwards is the shortwave measurement at satellite altitude. If this value is suspect, for any reason, the corresponding quality flag (SSF-35) bits will be set to non-zero. This variable is a 32 bit floating point number.

SSF-34   CERES WN filtered radiance, upwards [-10.0 to 50 W m^{-2} sr^{-1}]

The CERES WN filtered radiance, upwards is the window measurement at satellite altitude. If this value is suspect, for any reason, the corresponding quality flag (SSF-35) bits will be set to non-zero. This variable is a 32 bit floating point number. There may be a simulated value in this slot, but there is no window measurement by ERBE (thus for Pathfinder).

SSF-35   Quality flags [range TBD]

The quality flags are a set of bits that represent various instrument configurations and the Subsystem 1 radiance data evaluation. The contents of this flag are to include:

Bit #	Description	Values
1 .. 0	ERBE FOV flag	00 = hit earth
		01, 10, 11 = invalid for IES/SSF
3 .. 2	SW Radiance Flag	00 = Good output

5 .. 4	WN Radiance Flag	01 = Calculated but Bad output
7 .. 6	TOT Radiance Flag	10, 11 = Bad/Default output
9 .. 8	Instrument Mode	00= FAPS
		01 = RAPS
		10, 11 = Transitional/Other
13 .. 10	Elevation Scan Mode	0000 = Normal Earth Scan Profile
		0001 = Short Earth Scan Profile
		0011 = Nadir Scan Profile
		0010, 0100 = invalid for IES/SSF
		all others = Other Profiles
14	Azimuth Assembly Status	0 = Fixed
		1 = In Motion
30 .. 15	Spares	TBD
31	N/A	Always 0

This variable is a 32 bit integer and is copied from the IES.

SSF-36   ERBE SW unfiltered radiance, upwards [-10.0 to 510.0 W m^{-2} sr^{-1}]

The ERBE SW unfiltered radiance, upwards is the spectrally corrected shortwave radiance at the satellite. At night, the SW unfiltered radiance is set to 0. During the day, the unfiltered SW measurements are estimated from "good" filtered SW (SSF-33) and TOT (SSF-32) measurements. The filtered measurements are multiplied by regression coefficients which are a function of scene type, directional angles, and colatitude of the target point (see SSF-7). However, if the ERBE SW flux at TOA, upwards (SSF-39), which is calculated from this radiance is determined to be bad, for any reason, this variable will be set to the corresponding CERES default (see SSF-26). This variable is a 32 bit floating point number and is placed on the SSF by Subsystem 4.5.

SSF-37   ERBE LW unfiltered radiance, upwards [0.0 to 200.0 W m^{-2} sr^{-1}]

The ERBE LW unfiltered radiance, upwards is the spectrally corrected longwave radiance at the satellite. The unfiltered LW measurements are estimated from "good" filtered SW and TOT measurements. During the daytime, filtered SW (SSF-33) and TOT (SSF-32) measurements are required, but at night only TOT is needed. The filtered measurements are multiplied by regression coefficients which are a function of scene type, directional angles, and colatitude of the target point (see SSF-7). However, if the ERBE LW flux at TOA, upwards (SSF-40), which is calculated from this radiance is determined to be bad, for any reason, this variable will be set to the corresponding CERES default (see SSF-26). This variable is a 32 bit floating point number and is placed on the SSF by Subsystem 4.5.

SSF-38   CERES WN unfiltered radiance, upwards [0.0 to 50.0 W m^{-2} sr^{-1}]

The CERES WN unfiltered radiance, upwards is the spectrally corrected window radiance at

the satellite. The unfiltered WN measurements are estimated from "good" filtered WN (SSF-34) measurements. The filtered measurements are multiplied by a regression coefficient which is a function of scene type, directional angles, and colatitude of the target point (see SSF-7). However, if the CERES WN flux at TOA, upwards (SSF-41), which is calculated from this radiance is determined to be bad, for any reason, this variable will be set to the corresponding CERES default (see SSF-26). This variable is a 32 bit floating point number and is placed on the SSF by Subsystem 4.5. There may be a simulated value in this slot, but there is no window measurement by ERBE (thus for Pathfinder).

SSF-39   ERBE SW flux at TOA, upwards [0.0 to 1400.0 W m^{-2}]

The ERBE SW flux at TOA, upwards is the estimated shortwave exitance at the target point (see SSF-7). It is set to 0 at night, which is defined by a solar zenith angle equal to or larger than 86.5 degrees. The shortwave unfiltered radiance measurement (SSF-36) at satellite altitude is inverted to flux at the TOA using ATBD equation 4.5-1. The shortwave ADMs are a function of viewing zenith (SSF-22), solar zenith (SSF-23), and relative azimuth (SSF-24) at TOA. The SW flux is not calculated if the viewing zenith angle is equal to or larger than 70 degrees, if the inter-polated ADM value is equal to or larger than 2, or if there is no valid unfiltered SW measurement. This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.5.

SSF-40   ERBE LW flux at TOA, upwards [0.0 to 500.0 W m^{-2}]

The ERBE LW flux at TOA, upwards is the estimated longwave exitance at the target point (see SSF-7). The longwave unfiltered radiance measurement (SSF-37) at satellite altitude is inverted to flux at the TOA using ATBD equation 4.5-1. The longwave ADMs are a function of viewing zenith (SSF-22) and colatitude (SSF-7) at TOA. The LW flux is not calculated if the viewing zenith angle is equal to or larger than 70 degrees or if there is no valid unfiltered LW measurement. This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.5.

SSF-41   CERES WN flux at TOA, upwards [10.0 to 400.0 W m^{-2}]

The CERES WN flux at TOA, upwards is the estimated exitance, within the 8 - 12 μm window, at the target point (see SSF-7).   The window unfiltered radiance measurement (SSF-38) at satellite altitude is inverted to flux at the TOA using ATBD equation 4.5-1. The window ADMs are a function of viewing zenith (SSF-22) and colatitude (SSF-7) at TOA. The WN flux is not calculated if the viewing zenith angle is equal to or larger than 70 degrees or if there is no valid WN measurement. This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.5. There may be a simulated value in this slot, but there is no window measurement by ERBE (thus for Pathfinder).

SSF-42   CERES downward SW surface flux, Model A [0.0 to 1400.0 W m^{-2}]

The CERES downward SW surface flux, Model A is the estimated downward shortwave flux at the surface based on the Li-Garand algorithm (ATBD 4.6). This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.6. For Pathfinder, this value is set to CERES default (see SSF-26).

SSF-43   CERES downward LW surface flux, Model A [0.0 to 700.0 W m^{-2}]

The CERES downward LW surface flux, Model A is the estimated downward longwave flux at the surface based on the Ramanathan-Inamdar model (ATBD 4.6). Currently, this value can only be computed for cloud-free and ice-free ocean surfaces and cloud-free tropical land surfaces. It requires CERES LW (SSF-37) and WN (SSF-38) unfiltered radiances and surface emissivities (SSF-53, 54) as inputs and cannot, otherwise, be computed. Algorithms which support cloud forcing and extra-tropical land are expected at a later time. This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.6. For Pathfinder, this value is set to CERES default (see SSF-26).

SSF-44   CERES downward WN surface flux, Model A [0.0 to 250.0 W m^{-2}]

The CERES downward WN surface flux, Model A is the estimated downward window flux at the surface based on the Ramanathan-Inamdar model (ATBD 4.6). Currently, this value can only be computed for cloud-free and ice-free ocean surfaces and cloud-free tropical land surfaces. When combined with the downward nonWN surface flux component, one gets the downward LW surface flux (SSF-43). Algorithms which support cloud forcing and extra-tropical land are expected at a later time. This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.6. For Pathfinder, this value is set to CERES default (see SSF-26).

SSF-45   CERES net SW surface flux, Model A [0.0 to 1400.0 W m^{-2}]

The CERES net SW surface flux, Model A is the estimated net shortwave flux at the surface based on the Li-Leighton model (ATBD 4.6). Net flux is defined as downwelling flux minus upwelling flux. This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.6. For Pathfinder, this value is set to CERES default (see SSF-26).

SSF-46   CERES net LW surface flux, Model A [-250.0 to 50.0 W m^{-2}]

The CERES net LW surface flux, Model A is the estimated net longwave flux at the surface based on the Ramanathan-Inamdar model (ATBD 4.6). It is computed by subtracting the surface emission, assuming black body radiation, from the CERES LW flux at surface, downwards. Therefore, it can only be computed when a valid CERES LW flux at surface, downwards exists. This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.6. For Pathfinder, this value is set to CERES default (see SSF-26).

SSF-47   CERES downward SW surface flux, Model B [0.0 to 1400.0 W m^{-2}]

No second algorithm for CERES downward SW surface flux has been defined at this time. Until one is defined, this parameter will contain the CERES default (see SSF-26). This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.6. For Pathfinder, this value is set to CERES default (see SSF-26).

SSF-48   CERES downward LW surface flux, Model B [0.0 to 700.0 W m^{-2}]

The CERES downward LW surface flux, Model B is the estimated downward longwave flux at the surface based on the Gupta model (ATBD 4.6). This value will be computed globally. This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.6. For Pathfinder, this value is set to CERES default (see SSF-26).

SSF-49   CERES net SW surface flux, Model B [0.0 to 1400.0 W m^{-2}]

No second algorithm for CERES net SW surface flux has been defined at this time. Until one is defined, this parameter will contain the CERES default (see SSF-26). This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.6. For Pathfinder, this value is set to CERES default (see SSF-26).

SSF-50   CERES net LW surface flux, Model B [-250.0 to 50.0 W m^{-2}]

The CERES net LW surface flux, Model B is the estimated net longwave flux at the surface based on the Gupta model (ATBD 4.6). It is computed globally by subtracting the surface emission, assuming black body radiation, from the CERES LW flux at surface, downwards. This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.6. For Pathfinder, this value is set to CERES default (see SSF-26).

SSF-51   ERBE spectral albedo [0.0 to 1.0]

The ERBE spectral albedo is an array of 6 fractions of estimated reflected shortwave radiation within the visible and near-infrared portions of the electromagnetic spectrum. The property of reflectance is intrinsic to the medium being illuminated, therefore, reflectivity is based on the surface type. The six band widths for which spectral reflectivity is estimated are 0.2 - 0.7 µm, 0.7 - 1.3 µm, 1.3 - 1.9 µm, 1.9 - 2.5 µm, 2.5 - 3.5 µm, and 3.5 - 4.0 µm. Subsystem 4.4 does a table lookup of the 6 spectral albedo values for each imager pixel within the ERBE FOV (see SSF-26) and then computes a PSF-weight bin-average (see SSF-26) for each band width. These variables are 32 bit floating point numbers and the array is placed in the SSF by Subsystem 4.4.

SSF-52   ERBE broadband surface albedo [0.0 to 1.0]

The ERBE broadband surface albedo is the energy weighted integral of the six spectral reflectances (SSF-51). To compute this value, Subsystem 4.4 does a table lookup of the broadband surface albedo for each imager pixel within the ERBE FOV (see SSF-26) and then computes a PSF-weighted bin-average (see SSF-26). This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.4.

SSF-53   ERBE LW surface emissivity [0.0 to 1.0]

The ERBE LW surface emissivity is the PSF-weighted bin-average (see SSF-26) of the estimated fractional amount of radiation emitted by the surface over the entire longwave spectrum. Subsystem 4.4 does a table lookup of the LW surface emissivity for each imager pixel within the ERBE FOV (see SSF-26) and then computes a PSF-weighted bin-average. This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.4.

SSF-54   CERES WN surface emissivity [0.0 to 1.0]

The CERES WN surface emissivity is the PSF-weighted bin-average (see SSF-26) of the estimated fractional amount of radiation emitted by the surface within the 8 - 12 µm band width. It is computed in the same manner as the LW surface emissivity (SSF-53). This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.4. For Pathfinder, this parameter can be ignored.

SSF-55   Number of imager pixels in ERBE FOV [0 to 9000]

The number of imager pixels in ERBE FOV is a count of the actual number of imager pixels (see SSF-26) which are within the ERBE FOV (see SSF-26). For an example, refer to equation (26) in NOTE 2. The ERBE FOV is a rectangular grid that approximates the 95% energy area with respect to the Point Spread Function (PSF) (see SSF-26). There is no PSF weighting associated with this variable. This variable is a 16 bit integer and is placed in the SSF by Subsystem 4.4.

SSF-56   Imager percent coverage [0 to 100 percent]

The Imager percent coverage is the effective area of the ERBE FOV (see SSF-26) observed by the imager. Only those ERBE FOV's with at least 75% coverage are recorded on the SSF. Each angular bin (see SSF-26) within the ERBE FOV is considered "observed" if 1 or more imager pixels (see SSF-26) are within the angular bin. All observed angular bins are Point Spread Function (PSF) (see SSF-26) weighted to derive the percent coverage. This 16 bit integer variable is at bin resolution and is placed in the SSF by Subsystem 4.4.

SSF-57   Precipitable Water [0.001 to 8 cm]

Precipitable water is the water vapor burden from the surface to TOA (see SSF-7) in cm or, equivalently, g/cm^2. When over water, microwave precipitable water is preferred. However, if microwave precipitable water is unavailable or the region is not over water, meteorological precipitable water will be used instead. This variable is a 32 bit floating point number which is copied from one of the precipitable water fields on MOA. It is not based on imager pixel data, and it is placed on the SSF by Subsystem 4.6. MOA Precipitable water will be at the same resolution as the source grid from which it was obtained; precipitable water does not get regrid to the CERES grid nor are the meteorological precipitable water and the microwave precipitable water neccessarily on the same grid. For Pathfinder, this value is set to CERES default (see SSF-26).

SSF-58   Flag, source precipitable water [0 to 200]

The Flag, source precipitable water indicates the source of the precipitable water value copied from MOA. If microwave precipitable water is used, 100 is added to the MOA Flag, Source Microwave Column Precipitable Water and copied into this slot. If meteorological precipitable water is used, the MOA Flag, Source Meteorological Profiles is directly copied into this slot. In a 10/10/96 phone conversation with Lisa Coleman, Lisa stated that a flag value of 0 indicates no available source. Also, whenever a source flag is set to 0, the corresponding values should be set to the CERES default (see SSF-26). Therefore, if and only if this flag is 0 should precipitable water be set to the CERES default. This 16 bit integer is based on MOA Flag, Source Microwave Column Precipitable Water and MOA Flag, Source Meteorological Profiles. It is placed on the SSF by Subsystem 4.6. For Pathfinder, this value should be set to CERES default (see SSF-26).

SSF-59   Shadowed imager pixels percent coverage [0 to 100 percent]

Shadowed imager pixel percent coverage is the PSF-weighted (see SSF-26) percent of angular bins (see SSF-26) within the ERBE FOV (see SSF-26) which had at least one imager pixel containing shadow. Shadow, on an imager pixel basis, is determined in the Clouds subsystem. All imager pixels (see SSF-26), regardless of their cloud content, may contain shadow. Shadow is not limited to clear imager pixels. Any angular bin which contains an imager pixel with shadow is defined to have shadow. If shadow is uncertain for all angular bins within the ERBE FOV, the

shadowed imager pixels percent coverage is set to CERES default (see SSF-26). If there are no angular bins with shadow, or if the PSF-weighted percentage of shadow is less than 0.5%, the shadowed imager pixels percent coverage is set to 0. This 16 bit integer is placed in the SSF by Subsystem 4.4.

SSF-60   Imager Sunglint percent coverage [0 to 100 percent]

Imager sunglint percent coverage is the PSF-weighted (see SSF-26) percent of angular bins (see SSF-26) within the ERBE FOV (see SSF-26) which had at least one imager pixel containing sunglint, **as observed by the imager**. Sunglint, on an imager pixel basis, is determined in subsystem 4.1. Only clear imager pixels (see SSF-26) over water between latitudes of 60N to 60S can contain sunglint. Any angular bin which contains an imager pixel with sunglint is defined to have sunglint. If sunglint is uncertain for all clear angular bins within the ERBE FOV, the sunglint percent coverage is set to the CERES default (see SSF-26). If there are no angular bins with sunglint, or if the PSF-weighted percentage of sunglint is less than 0.5%, the sunglint percent coverage is set to 0. This 16 bit integer is placed on the SSF by Subsystem 4.4.

SSF-61   Imager-based snow/ice percent coverage [0 to 100 percent]

The imager-based snow/ice percent coverage is the PSF-weighted (see SSF-26) percent of angular bins (see SSF-26) within the ERBE FOV (see SSF-26) that had at least one clear imager pixel containing surface snow or ice as determined from the analysis in the Clouds subsystem 4.1. Currently only those clear imager pixels (see SSF-26) which have latitudes over 50 degrees, fall on mountains, or fall in an area which the microwave-based snow map indicates as snow are tested by for snow/ice by the Clouds subsystem. Snow/ice can only be determined for clear imager pixels, where clear means no indication of cloud from the subgrid cloud mask (see SSF-69). Any angular bin which contains an imager pixel with snow/ice is defined to be a snow/ice bin. If snow/ice is uncertain for all clear angular bins within the ERBE FOV, the percent coverage is set to the CERES default (see SSF-26). If there are no angular bins with snow/ice, or if the PSF-weighted percentage of snow/ice is less than 0.5%, the imager-based snow/ice percent coverage is set to 0. This snow/ice coverage is completely independent of the snow and ice surface types discussed in SSF-27. The snow and ice surface types come from SURFMAP, the imager-based snow/ice are derived by the Clouds subsystem on an imager pixel basis. This 16 bit integer is placed on the SSF by Subsystem 4.4.

SSF-62   Imager-based fire percent coverage [0 to 100 percent]

The imager-based fire percent coverage is the PSF-weighted (see SSF-26) percent of angular bins (see SSF-26) within the ERBE FOV (see SSF-26) that had at least one clear imager pixel containing fire as determined in subsystem 4.1.   Fire can only be determined for clear imager pixels (see SSF-26) and is currently limited to forests. Any angular bin which contains an imager pixel with fire is defined to be a fire bin. If fire is uncertain for all clear angular bins within the ERBE FOV, the percent coverage is set to the CERES default (see SSF-26). If there are no angular bins with fire or if the PSF-weighted percentage of fire is less than 0.5%, the imager-based fire percent coverage is set to 0. This 16 bit integer is placed on the SSF by Subsystem 4.4.

SSF-63   Imager-based aerosol percent coverage [0 to 100 percent]

The imager-based aerosol percent coverage is the PSF-weighted (see SSF-26) percent of angular bins (see SSF-26) within the ERBE FOV (see SSF-26) that had at least one clear imager

pixel containing one or more of the thicker aerosol types defined in SSF-64. Currently, there is only one aerosol detection algorithm - daytime smoke over forested areas. Aerosol can only be determined for clear imager pixels (see SSF-26). Any angular bin which contains an imager pixel with aerosol is defined to have aerosol. If aerosol is uncertain for all clear angular bins within the ERBE FOV, the percent coverage is set to the CERES default (see SSF-26). If there are no angular bins with these aerosols or if the PSF-weighted percent coverage is less than 0.5%, the imager-based aerosol percent coverage is set to 0. This 16 bit integer is placed on the SSF by Subsystem 4.4.

SSF-64   Flag, type of aerosol [0 to 9999]

The flag, type of aerosol indicates the types of thicker aerosols which were detected in the ERBE FOV (see SSF-26). The flag may contain up to 4 digits, where each digit corresponds to a thicker aerosol type. The right most digit always corresponds to the aerosol with the largest weighted percent coverage. If there are additional aerosols in the ERBE FOV, the corresponding digits are placed in the aerosol type such that the weighted percent coverages of the aerosols are ascending as one moves to the right. A ERBE FOV can only contain aerosol type information for the 4 most prevalent aerosols found.
The defined thicker aerosol types are:

> 1 - smoke
> 2 - dust (blowing sand)
> 3 - ash (volcanic)
> 4 - oceanic haze
> 5 through 9 - reserved for future use

Example:

Aerosol percent coverage (SSF-63) = 90

Flag, type of aerosol = 12

90% of the ERBE FOV area is covered with dust and smoke. There is more dust (2) than smoke(1) in the ERBE FOV. If there are no thicker aerosols present in the ERBE FOV or if no thicker aerosols could be identified within the ERBE FOV, this parameter is set to default. These aerosols are completely independent of the aerosols for which a total aerosol visible optical depth is computed in SSF-70, and they are independent of the MOA total column aerosol optical depth. This 16 bit integer is placed on the SSF by subsystem 4.4.

SSF-65   Notes on general procedures [range TBD]

The notes on general procedures is a number which refers to a particular procedure or configuration note documented elsewhere. There are no notes currently defined. This variable is a 16 bit integer and is placed in the SSF by Subsystem 4.4.

SSF-66   Notes on cloud algorithms [range TBD]

The notes on cloud algorithms is a number which refers to a particular algorithm note made by the Clouds subsystems 4.1 - 4.3 and copied directly from Cookie Dough. It's meaning is documented elsewhere. There are no notes currently defined. This variable is a 16 bit integer and is placed in the SSF by Subsystem 4.4.

SSF-67   Mean imager viewing zenith over ERBE FOV [0.0 to 90.0 degrees]

The mean imager viewing zenith over ERBE FOV is the average viewing zenith angle based

on all the imager pixels (see SSF-26) that fall within this ERBE FOV (see SSF-26). It is not PSF-weighted (see SSF-26). This variable is a 32-bit floating point number and is placed in the SSF by Subsystem 4.4.

SSF-68   Mean imager relative azimuth angle over ERBE FOV [0.0 to 360.0 degrees]

The mean imager relative azimuth angle over the ERBE FOV is determined by decomposing the azimuth angle into its x and y components. These components are averaged for all the imager pixels (see SSF-26) that fall within the ERBE FOV (see SSF-26) and then reconstructed into the average relative azimuth. It is not PSF-weighted (see SSF-26) and is at bin resolution. This variable is a 32-bit floating point number and is placed in the SSF by Subsystem 4.4.

SSF-69   Clear area percent coverage at subpixel resolution [0 to 100 percent]

The clear area percent coverage is computed from the highest resolution imager data available. For TRMM, the VIRS imager has only one resolution - 2km. For MODIS, we anticipate using the 0.25-km resolution data from the visible channel to derive a cloud mask at higher resolution than the other 1-km MODIS channels (hence the term subpixel). The clear area percent coverage is based on the subpixel level cloud fraction and should not be confused with SSF-106. When the imager data are available at only one resolution and at night, SSF-69 and SSF-106 will contain the same value.

$$C_{clr} = 100 * (1 - f_{cld})$$

The clear area percent coverage is PSF-weighted (see SSF-26). See NOTE 2 for complete description and refer to equation (29) for an example. This variable will be set to 0 when the percent coverage is less than 0.5%. This 16 bit integer is placed on the SSF by Subsystem 4.4.

SSF-70   Total aerosol visible optical depth in clear area [0.0 to 2.0]

The total aerosol visible optical depth in clear area is a PSF-weighted (see SSF-26) mean of the thinner aerosols. At the imager pixel level, the total visible optical depth is computed for sun-glint free, clear ocean imager pixels (see SSF-26) using a Stowe algorithm. Subsystem 4.4 computes a PSF-weighted mean total aerosol visible optical depth using the clear area at imager resolution. See ATBD equation 4.4-17. If none of the clear imager pixels have a valid total visible optical depth or if the clear area percent coverage at imager resolution is less than 0.5%, this variable is set to default. This parameter is independent of both the thicker aerosols discussed in SSF-63 and SSF-64 and the MOA total column aerosol optical depth. This 32 bit floating point number is placed on the SSF by subsystem 4.4.

SSF-71   Total aerosol effective radius in clear area [0.0 to 20.0 μm]

The total aerosol effective radius in clear area is currently undefined and, therefore, always set to CERES default (see SSF-26). This 32 bit floating point number is placed on the SSF by subsystem 4.4.

SSF-72   Imager-based surface skin temperature [175.0 to 375.0 K]

The imager-based surface skin temperature is the estimated from the clear-sky 11μm radiance using a narrowband radiative transfer algorithm which also requires MOA temperature and humidity inputs. Subsystem 4.1 selects only those imager pixels (see SSF-26) which are clear and

computes a surface skin temperature using the MOA temperature/humidity profile associated with the clear-sky imager pixels and Dave Kratz's correlated-K technique. In Subsystem 4.4, the derived surface skin temperatures are PSF-weighted (see SSF-26) using the clear area at imager resolution to provide a mean skin temperature.   If none of the clear imager pixels have a valid surface skin temperature or if the clear area percent coverage at imager resolution is less than 0.5%, this variable is set to the CERES default (see SSF-26). The imager-based surface skin temperature is independent of the MOA surface skin temperature, although it is hoped that they would be very similar. This variable is a 32 bit floating point number and is placed in the SSF by Subsystem 4.4.

SSF-73   Cloud layer area percent coverage   [0 to 100 percent]

The cloud layer area percent coverage is the PSF-weighted (see SSF-26) cloud cover over the ERBE FOV (see SSF-26) for the corresponding cloud layer at imager resolution. There are currently 2 cloud layers defined per ERBE FOV, where layer 1 is the lowest in height and layer 2, if it exists, is above layer 1. For a discussion about how cloud layers are detected and defined, refer to Note 1. This parameter contains only the percent coverage of a particular cloud layer over the footprint. It does not take into account overlap of the 2 cloud layers. Therefore, the sum of the 2 coverages can exceed 100. If only layer 1 is present, then the cloud layer area percent coverage for layer 2 will be set to 0. Similarly, if the ERBE FOV is completely clear, then both cloud layer area percent coverages will be set to 0. See Note 1, equation (30) for an example. If the cloud layer coverage is less than 0.5%, then the cloud layer should be discarded. If cloud layer 1 is discarded because coverage is less than 0.5% and a cloud layer 2 exists, layer 2 becomes layer 1. If cloud layer 1 is discarded and there is no layer 2, then layer one's area percent coverage is set to 0. When a cloud layer percent coverage is set to 0, all the following variables for the layer will be filled in with the CERES default (see SSF-26). This variable is a 16 bit integer and is placed on the SSF by subsystem 4.4.

SSF-74   Mean cloud visible optical depth for cloud layer [0.0 to 400.0]

The mean cloud visible optical depth for cloud layer is a PSF-weighted bin-average (see SSF-26)d, visible optical depth values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid optical depth values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). At night the mean cloud visible optical depth for cloud layer is always set to CERES default. This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-75   Stddev of cloud visible optical depth for cloud layer [range TBD]

The stddev of cloud visible optical depth for cloud layer is a PSF-weighted (see SSF-26) standard deviation of the bin-averaged visible optical depth values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF. See Note 1, equation (34) for an example and compete definition.   If there are no imager pixels with valid optical depth values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES

default (see SSF-26).   This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-76   Mean logarithm of cloud visible optical depth for cloud layer [0.0 to 6.0]

The mean logarithm of cloud visible optical depth for cloud layer is a PSF-weighted bin-average (see SSF-26) logarithms of the visible optical depth values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height category. See Note 1, equation (32) for an example and compete definition. If there are no imager pixels with valid optical depth values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-77   Stddev of logarithm of cloud visible optical depth for cloud layer [range TBD]

The stddev of logarithm of cloud layer cloud visible optical depth for cloud layer is a PSF-weighted (see SSF-26)standard deviation of the bin-averaged logarithm of the visible optical depth values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid optical depth values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26).   This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-78   Mean cloud infrared emissivity for cloud layer [0.0 to 1.0]

The mean cloud infrared emissivity for cloud layer is a PSF-weighted bin-average (see SSF-26) infrared emissivity values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid infrared emissivity values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-79   Stddev of cloud infrared emissivity for cloud layer [range TBD]

The stddev of cloud infrared emissivity for the cloud layer is a PSF-weighted (see SSF-26) standard deviation of the bin-averaged infrared emissivity values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid infrared emissivity values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-80   Mean liquid water path for cloud layer [range TBD g m^{-2}]

The mean liquid water path for cloud layer is a PSF-weighted bin-average (see SSF-26) water path values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a water particle phase for the cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid liquid water path values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26).   This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-81   Stddev of liquid water path for cloud layer [range TBD g m^{-2}]

The stddev of liquid water path for cloud layer is a PSF-weighted (see SSF-26) standard deviation of the bin-averaged water path values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a water particle phase for the cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition.   If there are no imager pixels with valid liquid water path values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-82   Mean ice water path for cloud layer [range TBD g m^{-2}]

The mean ice water path for cloud layer is a PSF-weighted bin-average (see SSF-26) water path values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have an ice particle phase for the cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition.   If there are no imager pixels with valid ice water path values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-83   Stddev of ice water path for cloud layer [range TBD g m^{-2}]

The stddev of   ice water path for cloud layer is a PSF-weighted (see SSF-26) standard deviation of the bin-averaged water path values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have an ice particle phase for the cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid ice water path values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-84   Mean cloud top pressure for cloud layer [0.0 to 1100.0 hPa]

The mean cloud top pressure for cloud layer is a PSF-weighted bin-average (see SSF-26) top pressure values associated with imager pixels (see SSF-26) which fall within the current ERBE

FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid cloud top pressure values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-85   Stddev of cloud top pressure for cloud layer [range TBD hPa]

The stddev of cloud top pressure for cloud layer is a PSF-weighted (see SSF-26) standard deviation of the bin-averaged top pressure values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid cloud top pressure values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-86   Mean cloud effective pressure for cloud layer [0.0 to 1100.0 hPa]

The mean cloud effective pressure for cloud layer is a PSF-weighted bin-average (see SSF-26) effective pressure values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid cloud effective pressure values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-87   Stddev of cloud effective pressure for cloud layer [range TBD hPa]

The stddev of cloud effective pressure for cloud layer is a PSF-weighted (see SSF-26)-weighted standard deviation of the bin-averaged effective pressure values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid cloud effective pressure values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26).   This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-88   Mean cloud effective temperature for cloud layer [100.0 to 350.0 K]

The mean cloud effective temperature for cloud layer is a PSF-weighted bin-average (see SSF-26) effective temperature values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid cloud effective temperature values or if the cor-

responding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26).   This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-89   Stddev of cloud effective temperature for cloud layer [range TBD K]

The stddev of cloud effective temperature for cloud layer is a PSF-weighted (see SSF-26) standard deviation of the bin-averaged effective temperature values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid cloud effective temperature values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-90   Mean cloud effective height for cloud layer [0.0 to 20.0 km]

The mean cloud effective height for cloud layer is a PSF-weighted bin-average (see SSF-26) effective height values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid cloud effective height values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-91   Stddev of cloud effective height for cloud layer [range TBD km]

The stddev of cloud effective height for cloud layer is a PSF-weighted (see SSF-26) standard deviation of the bin-averaged effective height values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF. See Note 1, equation (32) for an example and complete definition.   If there are no imager pixels with valid cloud effective height values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-92   Mean cloud base pressure for cloud layer [0.0 to 1100.0 hPa]

The mean cloud base pressure for cloud layer is a PSF-weighted bin-average (see SSF-26) base pressure values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid cloud base pressure values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-93   Stddev of cloud base pressure for cloud layer [range TBD hPa]

   The stddev of cloud base pressure for cloud layer is a PSF-weighted (see SSF-26) standard deviation of the bin-averaged base pressure values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid cloud base pressure values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-94   Mean water particle radius for cloud layer [range TBD μm]

   The mean water particle radius for cloud layer is a PSF-weighted average of bin-averaged spherical water droplet model particle radius values associated with the imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud with water particle phase at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid water particle radius values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-95   Stddev of water particle radius for cloud layer [range TBD μm]

   The stddev of water particle radius for cloud layer is a PSF-weighted (see SSF-26) standard deviation of bin-averaged spherical water droplet particle radius values associated with the imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud with water particle phase at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid water particle radius values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-96   Mean ice particle effective diameter for cloud layer [range TBD μm]

   The mean ice particle radius for cloud layer is a PSF-weighted bin-average (see SSF-26) effective particle diameter values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud with ice particle phase at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid ice particle effective diameter values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-97   Stddev of ice particle effective diameter for cloud layer [range TBD µm]

The stddev of ice particle radius for cloud layer is a PSF-weighted (see SSF-26) standard deviation of the bin-averaged effective particle diameter values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud with ice particle phase at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition.   If there are no imager pixels with valid ice particle effective diameter values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-98   Mean cloud particle phase for cloud layer [1.0 to 2.0]

The mean cloud particle phase for cloud layer is a PSF-weighted bin-average (see SSF-26) particle phase values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid cloud particle phase values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-99   Stddev of cloud particle phase for cloud layer [0.0 to 1.0]

The stddev of cloud particle phase for cloud layer is a PSF-weighted (see SSF-26) standard deviation of the bin-averaged particle phase values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid cloud particle phase values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-100   Mean vertical aspect ratio for cloud layer [0.0 to 20.0]

The mean vertical aspect ratio for cloud layer is a PSF-weighted bin-average (see SSF-26) vertical aspect ratio values associated with imager pixels (see SSF-26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF. See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid vertical aspect ratio values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-101   Stddev of vertical aspect ratio for cloud layer [range TBD]

The stddev of vertical aspect ratio for cloud layer is a PSF-weighted (see SSF-26) standard deviation of   the bin-averaged vertical aspect ratio values associated with imager pixels (see SSF-

26) which fall within the current ERBE FOV (see SSF-26) and have a cloud at the corresponding height layer. The bin-averaged values are weighted by the imager pixel fraction of corresponding layer imager pixels to total imager pixels and PSF.   See Note 1, equation (32) for an example and complete definition. If there are no imager pixels with valid vertical aspect ratio values or if the corresponding cloud layer area percent coverage is set to 0, this variable is set to CERES default (see SSF-26). This variable is a 32 bit floating point number, and it is placed on the SSF by subsystem 4.4.

SSF-102   Percentiles of visible optical depth for cloud layer (13) [0.0 to 400.0]

The percentiles of visible optical depth for cloud layer are the 1, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99 percentiles, for the associated ERBE FOV (see SSF-26) and cloud layer, of the visible optical depth. For the percentiles to make sense, there must be at least 100 imager pixels (see SSF-26) of this cloud layer in the ERBE FOV. Otherwise, these percentiles are set to CERES default (see SSF-26). The percentiles are computed by ordering the visible optical depths from smallest to largest and picking off the values at the designated points. The percentiles are 32 bit floating point numbers, and they are placed on the SSF by subsystem 4.4.

SSF-103   Percentiles of IR emissivity for cloud layer (13) [range TBD]

The percentiles of IR emissivity for cloud layer are the 1, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99 percentiles, for the associated ERBE FOV (see SSF-26) and cloud layer, of the 11 μm emissivity. For the percentiles to make sense, there must be at least 100 imager pixels (see SSF-26) of this cloud layer in the ERBE FOV. Otherwise, these percentiles are set to CERES default (see SSF-26). The percentiles are computed by ordering the visible optical depths from smallest to largest and picking off the values at the designated points. The percentiles are 32 bit floating point numbers, and they are placed on the SSF by subsystem 4.4.

SSF-104   Overlap condition weighted area percentages [0 to 100 percent]

$$C_{clr} = \text{clear overlap weighted area percentage} = 100\left(\left(\sum_{S_i}\omega_i f_{clr}^i\right)\Big/\left(\sum_{S_i}\omega_i\right)\right)$$

$$C_{A/O} = \text{lower cloud overlap weighted area percentage} = 100\left(\left(\sum_{S_i}\omega_i f_{A/O}^i\right)\Big/\left(\sum_{S_i}\omega_i\right)\right)$$

$$C_{B/O} = \text{upper cloud overlap weighted area percentage} = 100\left(\left(\sum_{S_i}\omega_i f_{B/O}^i\right)\Big/\left(\sum_{S_i}\omega_i\right)\right)$$

$$C_{B/A} = \text{upper over lower cloud weighted area percentage} = 100\left(\left(\sum_{S_i}\omega_i f_{B/A}^i\right)\Big/\left(\sum_{S_i}\omega_i\right)\right)$$

The overlap condition weighted area percentage is the PSF-weighted (see SSF-26) portion of the ERBE FOV, at the imager resolution, for the two cloud layers. The 4 overlap conditions are:
    1. clear
    2. lower cloud
    3. upper cloud
    4. upper over lower cloud
The overlap condition weighted area percentages always sum to 100 in a given ERBE FOV. If

there is only one cloud layer, its weighted area percentage is always placed in the lower cloud overlap slot. Any overlap conditions which do not exist within the ERBE FOV have a weighted area percentage of 0. For example, if there is only one cloud layer, the upper cloud overlap and the upper over lower cloud overlap percent coverages are set to 0. Similarly, if there are no clouds, the lower, upper, and upper over lower overlap percent coverages are set to 0. No overlap conditions should be set to CERES default (see SSF-26). This array of four 16 bit integers is placed on the SSF by subsystem 4.4.

SSF-105   Imager channel central wavelength [0.4 to 15.0 μm]

The imager channel central wavelength is an array of the 5 imager channel central wavelengths for which footprint imager radiance statistics will be recorded. On an imager pixel level, radiance values for all imager channels of possible interest are saved. Subsystem 4.4 then determines which 5 imager channels are of interest for this ERBE FOV (see SSF-26) and records those imager channel central wavelengths in this array. The imager channels are saved as an array of five 32 bit floating point numbers.

SSF-106   Clear area percent coverage at imager resolution [0 to 100 percent]

$$\tilde{C}_{clr} = \text{clear area percent coverage at imager resolution} = 100\left(\left(\sum_{S_i}\omega_i f^i_{clr}\right)\Big/\left(\sum_{S_i}\omega_i\right)\right)$$

Where: S_i is the set of indices for angular bins (see SSF-26) which contain one or more imager pixels (see SSF-26)

ω_i is the integral of the Point Spread Function (PSF) over the ith angular bin

f^i_{clr} = fraction of single imager pixels defined as clear within the angular bin = n^i_{clr} / n^i

n^i_{clr} is the number of clear imager pixels, imager pixels with cloud fraction of 0.0, in the ith angular bin

n^i is the total number of imager pixels in the ith angular bin

The clear area coverage at imager resolution is discussed at length in NOTE 2. If this parameter is set to 0, then all the clear footprint area parameters should be set to CERES default (see SSF-26). This parameter is the same as the clear overlap percent coverage in SSF-104. This 16 bit integer is saved to the SSF by Subsystem 4.4.

SSF-107   Overcast area percent coverage at imager resolution

$$\tilde{C}_{ov} = \text{overcast area percent coverage at imager resolution} = 100\left(\left(\sum_{S_i}\omega_i f^i_{ov}\right)\Big/\left(\sum_{S_i}\omega_i\right)\right)$$

Where: S_i is the set of indices for angular bins (see SSF-26) which contain one or more imager pixels (see SSF-26)

ω_i is the integral of the Point Spread Function (PSF) over the ith angular bin (see SSF-26)

f^i_{ov} = fraction of single imager pixels defined as overcast within the angular bin = n^i_{ov} / n^i

n^i_{ov} is the number of overcast imager pixels with cloud fraction of 1.0, in the ith angular bin

n^i is the total number of imager pixels in the ith angular bin

The overcast area coverage at imager resolution is discussed at length in NOTE 2. This 16 bit integer is saved to the SSF by Subsystem 4.4.

SSF-108   Mean of imager radiances over clear area [range TBD W m^{-2} sr^{-1} μm^{-1}]

The mean imager radiance over the clear area is a PSF-weighted (see SSF-26) average of the radiance associated with clear imager pixels (see SSF-26) for each of the five channels used in processing the footprint (Identified in SSF-105). An arithmetic mean is taken of all imager pixels within the angular bin (see SSF-26) before they are weighted by the imager pixel fraction of clear to total imager pixels and PSF. See Equation 41 in Note 1. If there are any clear imager pixels with valid imager radiance values within the ERBE FOV (see SSF-26), this variable will be set to the actual value, even if the clear area percent coverage rounds to 0. If there are no clear imager pixels or if there are no imager pixels with valid imager radiance values, this variable is set to CERES default (see SSF-26). Missing radiances will be filled by like values within the angular bin if available or using the footprint arithmetic average. This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

SSF-109   Stddev of imager radiances over clear area [range TBD W m^{-2} sr^{-1} μm^{-1}]

The stddev of imager radiance over the clear area is a PSF-weighted (see SSF-26) standard deviation of the radiance associated with clear imager pixels (see SSF-26) for each of the five channels used in processing the footprint (Identified in SSF-105). An arithmetic mean is taken of all imager pixels within the angular bin (see SSF-26) before they are weighted by the imager pixel fraction of clear to total imager pixels and PSF. See Equation 42 in Note 1. If there are any clear imager pixels with valid imager radiance values within the ERBE FOV (see SSF-26), this variable will be set to the actual value, even if the clear area percent coverage rounds to 0. If there are no clear imager pixels or if there are no imager pixels with valid imager radiance values, this variable is set to CERES default (see SSF-26). Missing radiances will be filled by like values within the angular bin if available or using the footprint arithmetic average. This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

SSF-110   Mean of imager radiances over overcast area [range TBD W m^{-2} sr^{-1} μm^{-1}]

The mean imager radiance over the overcast area is a PSF-weighted (see SSF-26) average of the radiance associated with overcast imager pixels (see SSF-26) (defined as imager pixels with a cloud fraction percentage greater than or equal to 99) for each of the five channels used in processing the footprint (Identified in SSF-105). An arithmetic mean is taken of all imager pixels within the angular bin (see SSF-26) before they are weighted by the imager pixel fraction of overcast to total imager pixels and PSF. See Equation 43 in Note 1. If there are any overcast imager pixels with valid imager radiance values within the ERBE FOV (see SSF-26), this variable will be set to the actual value, even if the overcast area percent coverage rounds to 0. If there are no overcast imager pixels or if there are no imager pixels with valid imager radiance values, this variable is set to CERES default (see SSF-26). Missing radiances will be filled by like values within the

angular bin if available or using the footprint arithmetic average.This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

SSF-111   SSF-110 Stddev of imager radiances over overcast area [range TBD W m⁻² sr⁻¹ μm⁻¹]

The stddev of imager radiance over the overcast area is a PSF-weighted (see SSF-26) standard deviation of the radiance associated with overcast imager pixels (see SSF-26) for each of the five channels used in processing the footprint (Identified in SSF-105). An arithmetic mean is taken of all imager pixels within the angular bin (see SSF-26) before they are weighted by the imager pixel fraction of overcast to total imager pixels and PSF. See Equation 44 in Note 1. If there are any overcast imager pixels with valid imager radiance values within the ERBE FOV (see SSF-26), this variable will be set to the actual value, even if the overcast area percent coverage rounds to 0. If there are no overcast imager pixels or if there are no imager pixels with valid imager radiance values, this variable is set to CERES default (see SSF-26). This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

SSF-112   Mean of imager radiances over full ERBE FOV [range TBD W m⁻² sr⁻¹ μm⁻¹]

The mean of imager radiance over the ERBE FOV is a PSF-weighted (see SSF-26) average of the radiance associated with all imager pixels (see SSF-26) convolved in the current ERBE FOV (see SSF-26) for each of the five channels used in processing the footprint (Identified in SSF-105). An arithmetic mean is taken of all imager pixels within the angular bin (see SSF-26) before they are weighted by the PSF. See Equation 45 in Note 1. If there are any imager pixels with valid imager radiance values within the ERBE FOV, this variable will be set to the actual value. If there are no imager pixels with valid imager radiance values, this variable is set to CERES default (see SSF-26). This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

SSF-113   Stddev of imager radiances over full ERBE FOV [range TBD W m⁻² sr⁻¹ μm⁻¹]

The stddev of imager radiance over the ERBE FOV is a PSF-weighted (see SSF-26) standard deviation of the radiance associated with all imager pixels (see SSF-26) convolved in the current ERBE FOV (see SSF-26) for each of the five channels used in processing the footprint (Identified in SSF-105). An arithmetic mean is taken of all imager pixels within the angular bin (see SSF-26) before they are weighted by the PSF. See Equation 46 in Note 1. If there are any imager pixels with valid imager radiance values within the ERBE FOV, this variable will be set to the actual value. If there are no imager pixels with valid imager radiance values, this variable is set to CERES default (see SSF-26). This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

SSF-114   5th percentile of imager radiances over full ERBE FOV [range TBD W m⁻² sr⁻¹ μm⁻¹]

The 5th percentile of imager radiances for each of five spectral channels over each ERBE FOV is the radiance value exceeded by 95 percent of the readings from that spectral channel for that ERBE FOV (see SSF-26). PSF-weighting is not used in the computation of this number. A minimum of 20 radiances are required to calculate these values. If 20 radiances are not available,

this array is set to CERES default (see SSF-26). This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

SSF-115   95th percentile of imager radiances over full ERBE FOV [range TBD W m^{-2} sr^{-1} μm^{-1}]

The 95th percentile of imager radiances for each of five spectral channels over each ERBE FOV is the radiance value exceeded by 5 percent of the readings from that spectral channel for that ERBE FOV (see SSF-26). PSF-weighting is not used in the computation of this number. A minimum of 20 radiances are required to calculate these values. If 20 radiances are not available, this array is set to CERES default (see SSF-26). This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

SSF-116   Mean of imager radiances over cloud layer 1 (no overlap) [range TBD W m^{-2} sr^{-1} μm^{-1}]

The mean of imager radiance over cloud layer 1 (no overlap) is a PSF-weighted (see SSF-26) average of the radiance associated with cloud layer 1only imager pixels (see SSF-26). Cloud layer 1 only imager pixels are imager pixels that do not contain an upper layer that corresponds with layer 2. A calculation is done for each of the five channels used in processing the footprint (Identified in SSF-105). An arithmetic mean is taken of all imager pixels within the angular bin (see SSF-26) before they are weighted by the imager pixel fraction of layer 1 only to total imager pixels and PSF. See Equation 49 in Note 1. If there are any layer 1 imager pixels with valid imager radiance values within the ERBE FOV (see SSF-26), this variable will be set to the actual value, even if the cloud area percent coverage for layer 1 rounds to 0. If there are no cloud layer 1 only imager pixels or if there are no cloud layer 1 only imager pixels with valid imager radiance values, this variable is set to CERES default (see SSF-26). This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

SSF-117   Stddev of imager radiances over cloud layer 1 (no overlap) [range TBD W m^{-2} sr^{-1} μm^{-1}]

The stddev of imager radiance over cloud layer 1 (no overlap) is a PSF-weighted (see SSF-26) standard deviation of the radiance associated with cloud layer 1 only imager pixels (see SSF-26). Cloud layer 1 only imager pixels are imager pixels that do not contain an upper layer that corresponds with layer 2. A calculation is done for each of the five channels used in processing the footprint (Identified in SSF-105). An arithmetic mean is taken of all imager pixels within the angular bin (see SSF-26) before they are weighted by the imager pixel fraction of layer 1 only to total imager pixels and PSF. See Equation 50 in Note 1. If there are any layer 1 imager pixels with valid imager radiance values within the ERBE FOV (see SSF-26), this variable will be set to the actual value, even if the cloud area percent coverage for layer 1 rounds to 0. If there are no cloud layer 1only imager pixels or if there are no cloud layer 1 only imager pixels with valid imager radiance values, this variable is set to CERES default (see SSF-26). This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

SSF-118   Mean of imager radiances over cloud layer 2 (no overlap) [range TBD W m^{-2} sr^{-1}

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4

μ**m^{-1}]**

The mean of imager radiance over cloud layer 2 (no overlap) is a PSF-weighted (see SSF-26) average of the radiance associated with cloud layer 2 only imager pixels (see SSF-26). Cloud layer 2 only imager pixels are imager pixels that so not contain a lower layer that corresponds with layer 1. A calculation is done for each of the five channels used in processing the footprint (Identified in SSF-105). An arithmetic mean is taken of all imager pixels within the angular bin (see SSF-26) before they are weighted by the imager pixel fraction of layer 2 only to total imager pixels and PSF. See Equation 51 in Note 1. If there are any layer 2 imager pixels with valid imager radiance values within the ERBE FOV (see SSF-26), this variable will be set to the actual value, even if the cloud area percent coverage for layer 2 rounds to 0. If there are no cloud layer 2 only imager pixels or if there are no layer 2 only imager pixels with valid imager radiance values, this variable is set to CERES default (see SSF-26). This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

SSF-119   Stddev of imager radiances over cloud layer 2 (no overlap) [range TBD W m^{-2} sr^{-1} μm^{-1}]

The stddev of imager radiance over cloud layer 2 (no overlap) is a PSF-weighted (see SSF-26) standard deviation of the radiance associated with cloud layer 2 only imager pixels (see SSF-26). Cloud layer 2 only imager pixels are imager pixels that so not contain a lower layer that corresponds with layer 1. A calculation is done for each of the five channels used in processing the footprint (Identified in SSF-105). An arithmetic mean is taken of all imager pixels within the angular bin (see SSF-26) before they are weighted by the imager pixel fraction of layer 2 only to total imager pixels and PSF. See Equation 52 in Note 1. If there are any layer 2 only imager pixels with valid imager radiance values within the ERBE FOV (see SSF-26), this variable will be set to the actual value, even if the cloud area percent coverage for layer 2 rounds to 0. If there are no cloud layer 2 only imager pixels or if there are no cloud layer 2 only imager pixels with valid imager radiance values, this variable is set to CERES default (see SSF-26). This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

SSF-120   Mean of imager radiances over cloud layer 1 and 2 overlap [range TBD W m^{-2} sr^{-1} μm^{-1}]

The mean of imager radiance over cloud layer 1 and 2 overlap is a PSF-weighted (see SSF-26) average of the radiance associated with cloud imager pixels (see SSF-26) that have two layers which correspond to layer 1 and 2 for each of five channels. A calculation is done for each of the five channels used in processing the footprint (Identified in SSF-105). An arithmetic mean is taken of all imager pixels within the angular bin (see SSF-26) before they are weighted by the imager pixel fraction of overlap to total imager pixels and PSF. See Equation 53 in Note 1. If there are any overlap imager pixels with valid imager radiance values within the ERBE FOV (see SSF-26), this variable will be set to the actual value, even if the cloud area percent coverage for overlap rounds to 0. If there are no overlap imager pixels or if there are no overlap imager pixels with valid imager radiance values, this variable is set to CERES default (see SSF-26). This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

SSF-121   Stddev of imager radiances over cloud layer 1 and 2 overlap [range TBD W m^{-2}

sr^{-1} μm^{-1}]

The stddev of imager radiance over cloud layer 1 and 2 overlap is a PSF-weighted (see SSF-26) standard deviation of the radiance associated with cloud imager pixels (see SSF-26) that have two layers which correspond to layer 1 and 2 for each of five spectral channels. A calculation is done for each of the five channels used in processing the footprint (Identified in SSF-105). An arithmetic mean is taken of all imager pixels within the angular bin (see SSF-26) before they are weighted by the imager pixel fraction of overlap to total imager pixels and PSF. See Equation 54 in Note 1. If there are any overlap imager pixels with valid imager radiance values within the ERBE FOV (see SSF-26), this variable will be set to the actual value, even if the cloud area percent coverage for overlap rounds to 0. If there are no overlap imager pixels or if there are no overlap imager pixels with valid imager radiance values, this variable is set to CERES default (see SSF-26). This variable is an array of 5 32-bit floating point numbers, and it is placed on the SSF by subsystem 4.4.

NOTE 1

CERES Definitions of Clear, Broken, and Overcast Clouds

and Cloud Layers

and their Mean Imager Radiances

(or it ain't a cloud layer till the cookie cutter says it's a cloud layer)

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The CERES processing convolves (cookie cutter) the scanner point spread function (PSF) with the imager pixel data (cookie-dough) to determine cloud properties over the CERES field of view (FOV). Since the imager pixel data can be nonuniform, we divide the 95% energy FOV (footprint) into angular bins, average the pixels within a bin, and integrate over the bins to get footprint averages. These average cloud parameters are recorded on the SSF product. The purpose of this note is to define in detail the cloud parameters and how they are calculated in the presence of data dropout and empty bins. All discussions will assume MODIS imager data at a pixel resolution of 1km and a cloud mask at a subpixel resolution of 250m. Thus, for each imager pixel there is a $4\times4=16$ point cloud mask.

Determination of Broken and Overcast Clouds

The cookie-dough for a single pixel is defined in ATBD Table 4.4-3 and is reproduced here as Table 1. A single pixel is defined as clear, broken, or overcast by the cloud fraction f_{cld} (#2) which is derived from the subgrid cloud mask of zeroes and ones. If a pixel does not have a cloud fraction for whatever reason, the pixel is disregarded. Each 1km pixel has 16 neighboring points (4 by 4) in the cloud mask and we define the pixel cloud condition as follows:

clear $\quad\quad\quad f_{cld} = 0/16 = 0$

broken $\quad\quad\quad 1/16 \leq f_{cld} \leq 15/16$

overcast $\quad\quad\quad f_{cld} = 16/16 = 1$

Overcast cloud is usually defined as a cloud with a cloud fraction greater than 99%. Since 15/16 is 0.9375, we must have all 16 subgrid points classified as cloud (mask = 1) for overcast. Throughout this note we will use 16^{ths} to illustrate the algorithms. In practice some of the mask points could be missing or unreliable so that we will work with a real valued cloud fraction. This means that broken clouds are defined by $0.01 < f_{cld} < 0.99$.

We also define a clear, broken, and overcast fraction for an angular bin. If the ith angular bin contains n^i pixels, then we define the bin clear fraction as the fraction of single pixels defined as clear or

$$f^i_{clr} = n^i_{clr}/n^i . \tag{1}$$

The broken and overcast cloud fractions are defined similarly so that $f^i_{clr} + f^i_{bk} + f^i_{ov} = 1$. The "cloud" fraction for the ith bin is defined as the average of the single pixel cloud fractions or

$$f^i_{cld} = \frac{1}{n^i} \sum_{\text{all pixels}} f^{ij}_{cld} \tag{2}$$

where f^{ij}_{cld} is the cloud fraction (#2) for the jth pixel in the ith bin. We have defined four different fractions: clear, broken, overcast, cloud. Note that the clear, broken and overcast cloud fractions are at the pixel resolution of 1km and the cloud fraction (2) is at the subgrid resolution of 250m. A broken cloud pixel at 1km resolution contains clear and overcast at the 250m resolution. The cloud fraction averages the overcast (mask=1) at the subgrid resolution and is not equal to one minus the clear fraction. Neither is the cloud fraction equal to the sum of the broken and overcast cloud fractions.

The mean imager radiance for the ith bin is defined by

$$I^i = \frac{1}{n^i} \sum_{all\ pixel} I^{ij} \tag{3}$$

and the clear mean radiance for the bin is defined as

$$I^i_{clr} = \frac{1}{n^i_{clr}} \sum_{clr\ pixel} I^{ij}. \tag{4}$$

The broken and overcast mean radiances are similarly defined so that

$$I^i = f^i_{clr} I^i_{clr} + f^i_{bk} I^i_{bk} + f^i_{ov} I^i_{ov} . \tag{5}$$

If a single pixel is missing the imager radiance (bad or no data), then it is filled with the average of the other pixels in the bin with the same cloud condition. If there are no like pixels in the bin with good radiances, then the mean bin radiance for the cloud condition is filled with the weighted average of other like bin averages. This is necessary for mean radiances and fractions to balance as discussed later.

We next define five quantities of area coverage over the footprint: imager data, clear, broken, overcast, cloud. First, let us define S_i as the set of angular bin indices (the i's) that contain pixel data, and ω_i as the integral of the PSF over the ith bin. With these definitions we define the five "PSF weighted" area coverages as:

$$C_{imag} = \left(\sum_{S_i} \omega_i \right) \bigg/ \left(\sum_{all\ bins} \omega_i \right) \tag{6}$$

$$C_q = \left(\sum_{S_i} \omega_i f^i_q \right) \bigg/ \left(\sum_{S_i} \omega_i \right) \tag{7}$$

where the subscript "q" denotes clr, bk, ov, or cld. It follows that

$$\begin{aligned} C_{clr} + C_{bk} + C_{ov} &= 1 \\ C_{bk} + C_{ov} &\neq C_{cld} \end{aligned} \tag{8}$$

The imager radiance is averaged over the various area types. The mean radiance over the footprint is given by

$$I = \left(\sum_{S_i} \omega_i I^i \right) \Big/ \left(\sum_{S_i} \omega_i \right). \tag{9}$$

and

$$\bar{I}_q = \left(\sum_{S_i} \omega_i f_q^i I_q^i \right) \Big/ \left(\sum_{S_i} \omega_i f_q^i \right) \tag{10}$$

where "q" denotes clr, bk, or ov. With these definitions if follows that the area coverages and the mean radiances are in balance, or

$$C_{clr} \bar{I}_{clr} + C_{bk} \bar{I}_{bk} + C_{ov} \bar{I}_{ov} = \bar{I} \tag{11}$$

Because the area coverages sum to one (8) and the radiances are in balance (11), the SSF product does not record broken cloud quantities since they can be determined from

$$C_{bk} = 1 - (C_{clr} + C_{ov})$$
$$\bar{I}_{bk} = \frac{\bar{I} - (C_{clr}\bar{I}_{clr} + C_{ov}\bar{I}_{ov})}{C_{bk}}. \tag{12}$$

Moreover, for TRMM and the VIRS imager we do not have a subgrid cloud mask so that the single pixel cloud fraction (#2) will be either 0 or 1 which does not allow for broken pixels.

We can also average a general property "x" over the footprint. However, there are several different cases of general parameters and this discussion is beyond the scope of this paper and will be dealt with later.

A Numerical Example of Cloud Fraction and Radiance Determination

Now let us examine the numerical example (Example 1) given in Table 2. The numbers are hypothetical and do not represent a realistic case. The purpose is to show how the above definitions and equations are applied and how missing data is handled. We have assumed the foot-

print has 10 angular bins all of which contain imager pixels except for bin 9. All of the pixels were either clear or had one layer clouds (#1 of Table 1). Bin 2 contains one clear pixel and one cloudy pixel. Bin 6 contains 3 pixels. In the "Pixel Data" section we see the subgrid mask data given in 16$^{\text{ths}}$. Notice that clear pixels contain no cloud data such as cloud mask or cloud parameters. They do contain, however, the imager radiances. Actually, the cookie-dough contains many narrowband radiances. Only one radiance is given here for illustration.

Below the cookie-dough data are "Calculated Quantities". The PSF weights are dependent on the arrangement of the angular bins and the scanner Point Spread Function. These weights are computed off-line and are applicable to all footprints with the same angular bin structure and PSF. The values of ω_i were arbitrarily chosen to sum to one for numerical convenience. The number of pixels in each bin and the cloud classification fractions are given next. Bin 1 has 1 pixel which is clear or has a clear fraction of 1.0 or 100% clear. Bin 2 contained 2 pixels and is 50% clear and 50% broken cloud. The clear pixel has a "cloud" fraction of 0/16 and the other pixel has one of the 16 points in the cloud mask define as cloud (mask=1) so that its cloud fraction is 1/16. The average bin cloud fraction is thus 1/32.

In bin 2 we see the average imager radiance over the 1 clear pixel is 12. The average over the broken cloud area is 14. And since the fractions are both 50%, the mean radiance over the bin is 13. Bin 6 presents several illustrations. There are two overcast pixels, but only one has a radiance value. As mentioned above we fill the missing radiance value with the average of like pixels which for bin 6 is a radiance of 38 and the average bin overcast radiance is therefore 38. The single broken cloud pixel gives a broken radiance of 32. We weight these radiances with the appropriate fractions of 1/3 and 2/3 and determine the mean bin radiance as 36.

An additional illustration is presented by bin 4 that contains 1 pixel with a missing radiance. In this case we fill the bin radiance with the weighted average of the other like radiances, or

$$
= \frac{(.03)\left(\frac{1}{2}\right)(14) + (.10)\,(1)\,(29) + (.20)\left(\frac{1}{3}\right)(32) + (.15)\,(1)\,(34)}{(.03)\left(\frac{1}{2}\right) + (.10)\,(1) + (.20)\left(\frac{1}{3}\right) + (.15)\,(1)} = 3
$$

The mean of a general cloud parameter for a bin is just the arithmetic average of the available data. The mean parameter over the footprint is a weighted average.

We now calculate the footprint parameters:

$$S_i \ = \ \text{set of indices for observed bins}$$
$$= \ \{1,2,3,4,5,6,7,8,10\} \tag{13}$$

$$N \ = \ \text{number of imager pixels in FOV} \ = \ \sum_{S_i} n^i \tag{14}$$
$$= \ 1+2+1+1+1+3+1+1+1 \ = \ 12$$

$$C_{\text{imag}} \ = \ \text{imager area coverage} \ = \ \left(\sum_{S_i} \omega_i \right) \Big/ \left(\sum_{\text{all bins}} \omega_i \right) \tag{15}$$
$$= \ .02+.03+.10+.15+.20+.20+.15+.10+.02 = 0.97$$

$$C_{clr} \ = \ \text{clear area coverage} \ = \ \left(\sum_{S_i} \omega_i f_{clr}^i \right) \Big/ \left(\sum_{S_i} \omega_i \right) \tag{16}$$
$$= \ [(.02)(1)+(.03)(1/2)+(.10)(1)+(.02)(1)] \,/\, 0.97 \ = \ 0.16$$

$$C_{bk} \ = \ broken \ \text{cloud area coverage} \ = \ \left(\sum_{S_i} \omega_i f_{bk}^i \right) \Big/ \left(\sum_{S_i} \omega_i \right) \tag{17}$$
$$= \ [(.03)(1/2)+(.10)(1)+(.15)(1)+(.20)(1/3)+(.15)(1)] \,/\, 0.97 \ = \ 0.50$$

$$C_{ov} \ = \ overcast \ \text{cloud area coverage} \ = \ \left(\sum_{S_i} \omega_i f_{ov}^i \right) \Big/ \left(\sum_{S_i} \omega_i \right) \tag{18}$$
$$= \ [(.20)(1)+(.20)(2/3)] \,/\, 0.97 \ = \ 0.34$$

$$C_{cld} \ = \ \text{cloud area coverage} \ = \ \left(\sum_{S_i} \omega_i f_{cld}^i \right) \Big/ \left(\sum_{S_i} \omega_i \right) \tag{19}$$
$$= \ \left[\begin{array}{c} (.03)(1/32)+(.10)(13/16)+(.15)(15/16)+(.20)(16/16) \\ + \ (.20)(46/48)+(.15)(14/16) \end{array} \right] \,/\, 0.97 \ = \ 0.72$$

Note that (8) is verified or $0.16 + 0.50 + 0.34 = 1$ and $0.50 + 0.34 \neq 0.72$.

The mean imager radiances are as follows:

$$\bar{I}_{clr} = \text{mean imager radiance over clear area} = \left(\sum_{S_i} \omega_i f_{clr}^i I_{clr}^i\right)\Big/\left(\sum_{S_i} \omega_i f_{clr}^i\right)$$

$$= \frac{(.02)(1)(12)+(.03)(1/2)(12)+(.10)(1)(21)+(.02)(1)(17)}{(.02)(1)+(.03)(1/2)+(.10)(1)+(.02)(1)} = 18.45 \tag{20}$$

$$\bar{I}_{bk} = \text{mean imager radiance over broken cloud area} = \left(\sum_{S_i} \omega_i f_{bk}^i I_{bk}^i\right)\Big/\left(\sum_{S_i} \omega_i f_{bk}^i\right)$$

$$= \frac{(.03)(1/2)(14)+(.10)(1)(29)+(.15)(1)(31.19)+(.20)(1/3)(32)+(.15)(1)(34)}{(.03)(1/2)+(.10)(1)+(.15)(1)+(.20)(1/3)+(.15)(1)} = 31.19 \tag{21}$$

$$\bar{I}_{ov} = \text{mean imager radiance over overcast cloud area} = \left(\sum_{S_i} \omega_i f_{ov}^i I_{ov}^i\right)\Big/\left(\sum_{S_i} \omega_i f_{ov}^i\right)$$

$$= \frac{(.20)(1)(40)+(.20)(2/3)(38)}{(.20)(1)+(.20)(2/3)} = 39.20 \tag{22}$$

$$\bar{I} = \text{mean imager radiance over FOV} = \left(\sum_{S_i} \omega_i I^i\right)\Big/\left(\sum_{S_i} \omega_i\right)$$

$$= \frac{\left[\begin{array}{c}(.02)(12)+(.03)(13)+(.10)(29)+(.15)(31.19)+(.20)(40)\\ +(.20)(36)+(.15)(34)+(.10)(21)+(.02)(17)\end{array}\right]}{.02+.03+.10+.15+.20+.20+.15+.10+.02} = 31.91 \tag{23}$$

Note that (11) is verified or $(.1598)(18.45)+(.4966)(31.19)+(.3436)(39.20) = 31.91$.

Determination of Cloud Height Categories A and B

Cloud layers will be defined as being in one of four height categories (Figure 1) by their effective pressure (See Table 1, #24 and #35). In general a single footprint can contain clear areas and clouds in all four categories. However, we will restrict clouds within a single footprint to two layers and assign each cloud layer to the height category which contains the layer average pressure. Layer 1 is defined as the lowest layer (or only layer) and we will assign it to category A where A could be 1, 2, 3, or 4. If there is a second layer, then layer 2 is the highest layer and we assign it to category B where B could be 2, 3, or 4, but not the same as category A. The mean cloud data within an angular bin is defined as being in categories A and B. It is possible, however, for the effective pressure of a given angular bin to be outside of categories A and B, but recall we have defined layers and assigned each layer to the category containing its mean.

We now determine the two layers and the two categories A and B from the mean clouds within the bins. The mean cloud effective pressures (#24 and #35) can range over all 4 cloud categories, but we must restrict them to categories A and B for layers 1 and 2 as discussed above. If all bins are clear, then we have no cloud categories. Let us first consider the case where all cloudy bins contain only 1-layer clouds. There is no 2-layer clouds in the footprint. We can determine the mean x and standard deviation S of the effective pressure #24 over the n bins that contain a 1-layer cloud. It is possible that we have not one but two distinct single layers over the footprint. To test this, we order the pressures and determine the increment between increasing pressures. If the maximum increment is greater than 50 hPa, then we divide the pressures into two sets at the maximum increment and define two layers with $(\bar{x}_1, S_1, n_1)$ and $(\bar{x}_2, S_2, n_2)$ where $\bar{x} = \dfrac{1}{n}\sum_{i=1}^{n} x_i$

and $S^2 = \dfrac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$. If $t_\alpha = |(\bar{x}_1 - \bar{x}_2)| / \sqrt{S_1^2/n_1 + S_2^2/n_2}$ is greater than 2.13, then we have two distinct layers and define categories A and B with $\bar{x}_1$ and $\bar{x}_2$ so that A<B and category A is the lower cloud layer with the greater pressure. It is possible to have 2 distinct layer and both are in the same category. In this case, we do not divide but stay with one layer containing all $n = n_1 + n_2$ pixels. If t is less than 2.13, then the layers are not distinct and we have one layer and define category A with $\bar{x}$ where $n = n_1 + n_2$. If either n_1 or n_2 is less that 3, then we will not attempt the Student t test to separate the pressures but leave them in one layer.

We will use only one value for $t_\alpha = 2.13$. Since our minimum sample is 6 with 4 degrees of freedom, we can determine that a t_α of 2.13 implies a 90% confidence level. With the maximum sample of 64 for TRMM, we are 96% confident with 2.13.

Next, let us consider the case where all cloudy bins contain 2 cloud layers. We can determine $(\bar{x}, S, n)$ for the higher layer with #35. We can also test #35 for two distinct layers as above. If we have one layer, then we define category B with $\bar{x}$ and define category A with the mean of #24. If we have two distinct layers, then we define category A and B with $\bar{x}_1$ and $\bar{x}_2$ and put all

lower layers (#24) into either A or B depending on which is closest.

And finally, if we have within a single footprint some bins with one layer and some bins with two layers, then we combine the first two cases. From the bins with one layer we determine $(\bar{x}, S, n)$ from #24 and also test it for two distinct layers. If #24 yields one layer and defines category A'. We use the notation A' instead of A because it is not clear at this point whether the defined layer is low or high. After A' and B' have been defined, we set A and B such that A<B. Next we determine $(\bar{x}, S, n)$ from #35 for the bins with two layers and determine if #24 from the 1-layer case and #35 from the 2-layer case give distinctly different layers. If they are different, then category B' has been defined (provided A' and B' are not equal) and #24 from the 2-layer bins are put into the closest category. If they are not different, then clouds in the bins with one layer and the top layer of the 2-layer bins are in the same layer and #24 from the 2-layer cases defines category B'. If, however, we find that the bins with one layer define two distinct layers, then all the cloud layers in the two layer bins are put into the closest of these two distinct layers.

Whenever we determine two layers and two height categories A and B, we reexamine. The average pressure corresponding to A and to B are used to define two layers and each pressure from each bin is placed in the closest layer independent of what its designation was on the first pass. It is possible to start with a two layer cloud in a bin and upon reexamination put both layers into the same final layer or category. An example will help to demonstrate this.

Numerical Examples of Cloud Layer Determination

We now build on Example 1 and work through Example 2 as given in Table 3. The cloud mask and number of cloud layers for each imager pixel are the same as in Example 1. We now add the pixel effective pressure in each cloud layer and determine for the entire footprint if we have one cloud layer (layer A) or two distinct cloud layers (layer A and B) (see Fig. 1). This involves collecting the available data into "cloud layers" as compared to "clear", "broken", and "overcast clouds". All of the bins in example 2 are 100% clear or 100% 1-layer except for bin 2 which is 50% clear and 50% 1-layer. We will make use of these fractions later. The mean "bin" effective pressure is determined in the same way as we determined the general parameters, that is,

we assume uniformity over the bin and form the arithmetic average. Bin 6 is an example of this. Since we have the case where all cloudy bins are 1-layer clouds, we just collect the pressures in bins 2, 3, 4, 5, 6, and 7. The mean ordered pressures are {245, 250, 268, 320, 320, 335} and the increments are {5, 18, 52, 0, 15}. Since the largest increment of 52 is greater than 50, we proceed with two sets. The first set is {245, 250, 268} with $n_1 = 3$, $\bar{p}_1 = 254.33$, $S_1 = 12.10$ and the second set is {320, 320, 335} with $n_2 = 3$, $\bar{p}_2 = 325.00$, $S_2 = 8.66$. We next test for two distinct layers with the t test, or

$$
= \frac{\left|\bar{p}_1 - \bar{p}_2\right|}{\left[\dfrac{S_1^2}{n_1} + \dfrac{S_2^2}{n_2}\right]^{1/2}} = \frac{|254.33 - 325.00|}{\left[\dfrac{(12.10)^2}{3} + \dfrac{(8.66)^2}{3}\right]^{1/2}} = 8.23 > 2.12 \tag{24}
$$

Therefore, there are two layers with layer A with a pressure p_A=325.00 and layer B with pressure p_B=254.33. It will be simpler here to refer to layer 1 in cloud height category A as just layer A. On reexamination, all pressures remain in the same layer.

We now go to Example 3 where we have both 1-layer and 2-layer clouds (see Table 4). Some of the pixel data has changed from Example 2. The clear, 1-layer, and 2-layer fractions are determined as before. Within a bin we determine the mean pressure for clear, 1-layer, and 2-layer pixels. Bin 2 and 6 give examples how this is handled. We start with the 1-layer clouds in bins 2, 3, 4, 6, 10. The ordered pressures are {280, 290, 330, 335, 612} and the increments are {10, 40, 5, 277}. Since the largest increment of 277 is greater than 50, we would normally form two sets. However, since one of the sets has less than 3 pressures and since we require 3 samples to calculate a sample standard deviation, we do not separate the set but form one set (layer A') where $n_{A'} = 5$, $\bar{p}_{A'} = 369.40$, $S_{A'} = 137.74$. We notice that bin 10 with a pressure of 612 has been put into the wrong layer. But, if we separate into two layers at this point, we are establishing a layer with only one observation and then would have to force the other data values to conform to it. Since bin 10 is different, it could be erroneous. It seems best to proceed and reexamine at the end.

Next we collect all the pressures from the high layer of the 2 layer bins or from bins 5, 6, 7, 8 we have the mean pressures {340, 335, 350, 606} with n = 4, $\bar{p} = 407.75$, S = 132.31. We now test to see if this set is different than the layer A' set, or

$$\alpha = \frac{|369.40 - 407.75|}{\left[\dfrac{(137.74)^2}{5} + \dfrac{(132.31)^2}{4} \right]^{1/2}} = 0.42 < 2.1\ddot{.} \tag{25}$$

Since $t_\alpha < 2.13$ we can not justify two different sets so we combine the two or set $A' = \{280, 290, 330, 335, 612, 340, 335, 350, 606\}$ with $n_{A'} = 9$ and $\bar{p}_{A'} = 386.44$.

Layer B' is given by the lower layers of the 2-layer bins or set $B' = \{620, 638, 664, 710\}$ with $n_{B'} = 4$, $\bar{p}_{B'} = 658.00$. Since we already have two layers, layer A' and B', and we can only have 2 layers over a footprint, it makes no sense to test layer B' for two distinct layers. Besides, layer B' is composed of the lower, less-well-known layers. We prefer to rely on the 1-layer and upper layers. Now, since $\bar{p}_{A'} < \bar{p}_{B'}$ and layer A should have the greater pressure (see Fig. 1), we reverse the layers and define A and B such that $\bar{p}_A = 658.00$ and $\bar{p}_B = 386.44$. The next step is to use these two mean pressures and reexamine all pressures, putting them into the nearest layer. The new sets are set A = {620, 638, 664, 658, 612} with $n_A = 5$, $\bar{p}_A = 638.40$, $S_A = 22.78$ and set B = {280, 290, 335, 340, 330, 335, 350} with $n_B = 7$, $\bar{p}_B = 322.86$, $S_B = 26.75$. Notice that the layer in bin 10 correctly switched layers and that the two layers in bin 8 were combined into one layer. We will define layer A as height category 2 (lower middle clouds) since 500 $<(\bar{p}_A = 638.40) < 700$. We also define layer B as height category 3 (upper middle clouds) since $300 < (\bar{p}_B = 322.86) < 500$. Recall that we restricted clouds to 2 of the 4 cloud height categories over a footprint. Thus, even though bin 2 and 3 have clouds in category 4 (high clouds) defined by p < 300, they are combined with a layer whose center is in category 3. The mean pressure, $\bar{p}_B = 322.86$, and the standard deviation, $S_B = 26.75$, indicate that the boundary of 300 is only (322.85-300.00)/26.75 = 0.85 sigma away and that the layer may well contain cloud pressures on

both sides of the boundary.

And finally, we determine the layer pressures for each angular bin and the fraction of clear, layer A and layer B in each bin as. We now have enough information to determine the overlap fractions as shown in Table 4. These will be discussed in the next section.

SSF Data Product

The SSF (see Table 6) contains all the footprint data including clear, and overcast fractions (and the information to determine the broken fraction. see (12)) and the cloud layering information along with mean radiances over these areas. Let us use the numbers in Example 3 (Table 4) to numerical define several of the SSF parameters.

SSF-55: Number of imager pixels in the CERES FOV

From (13) and (14) we have

$$
\begin{aligned}
S_i &= \text{ set of indices for observed bins} \\
&= \{1,2,3,4,5,6,7,8,10\}
\end{aligned}
\tag{26}
$$

$$
\begin{aligned}
N &= \text{ number of imager pixels in FOV } = \sum_{S_i} n^i \\
&= 1+2+1+1+1+3+1+1+1 = 12
\end{aligned}
\tag{27}
$$

SSF-56: Imager percent coverage

From (6) we have

$$
\begin{aligned}
C_{\text{imag}} &= \text{ imager area coverage } = \left(\sum_{S_i} \omega_i\right) \Big/ \left(\sum_{\text{all bins}} \omega_i\right) \\
&= .02+.03+.10+.15+.20+.20+.15+.10+.02 = 0.97 \ (97\%)
\end{aligned}
\tag{28}
$$

SSF-69: Clear area percent coverage

The clear area coverage is at the highest resolution or at the subgrid resolution and should not be confused with SSF-106, the clear area percent coverage at imager resolution. If we have

no subgrid resolution, then SSF-64 and SSF-106 are identical. We determine the clear coverage by calculating the cloud fraction and subtracting it from 1.0, or from (2) and (7) we have

$$C_{cld} = \text{cloud area coverage} = \left(\sum_{S_i} \omega_i f^i_{cld}\right) \Big/ \left(\sum_{S_i} \omega_i\right)$$

$$= \left[\begin{array}{l}(.03)(1/32)+(.10)(13/16)+(.15)(15/16)+(.20)(16/16) \\ + (.20)(46/48)+(.15)(14/16)+(.10)(9/16)+(.02)(3/16)\end{array}\right] \Big/ 0.97 = 0.807 \quad (29)$$

$$C^*_{clr} = 1 - C_{cld} = 1 - 0.807 = 0.192 \ (19\%)$$

SSF-73: Cloud category area percent coverage

We have two cloud layers in category A and B. We will denote these simply as layer A and B and their area coverage as C_A and C_B. Similar to (7) we have

$$C_A = \text{cloud layer A area coverage} = \left(\sum_{S_i} \omega_i f^i_A\right) \Big/ \left(\sum_{S_i} \omega_i\right)$$

$$= [(.20)(1)+(.20)(2/3)+(.15)(1)+(.10)(1)+(.02)(1)] \, / \, 0.97 = 0.622 \ (62\%) \qquad (30)$$

and

$$C_B = [(.03)(1/2)+(.10)(1)+(.15)(1)+(.20)(1)+(.20)(1)+(.15)(1)]/0.97$$

$$= 0.840 \ (84\%) \qquad (31)$$

Notice that because of overlay of layers A and B, $C_{clr} + C_A + C_B > 100\%$.

SSF-86: Mean cloud effective pressure for cloud category

The mean cloud pressure over the footprint is a weighted average and should not be confused with the arithmetic average pressure used to determine cloud layers A and B. Similar to (10) we have

$$\bar{p}_A = \text{Cloud layer A mean effective pressure} = \left(\sum_{S_i} \omega_i f^i_A \bar{p}^i_A\right) \Big/ \left(\sum_{S_i} \omega_i f^i_a\right)$$

$$= \frac{\left[\begin{array}{c}(.20)(1)(620)+(.20)(2/3)(638)+(.15)(1)(664) \\ +(.10)(1)(658)+(.02)(1)(612)\end{array}\right]}{(.20)(1)+(.20)(2/3)+(.15)(1)+(.10)(1)+(.02)(1)} = 640.95 \qquad (32)$$

and

$$\bar{p}_B = \frac{\left[\begin{array}{c}(.03)(1/2)(280)+(.10)(1)(290)+(.15)(1)(335)\\+(.20)(1)(340)+(.20)(1)(333.33)+(.15)(1)(350)\end{array}\right]}{(.03)(1/2)+(.10)(1)+(.15)(1)+(.20)(1)+(.20)(1)+(.15)(1)} = 332.04 \qquad (33)$$

SSF-87: Stddev of cloud effective pressure for cloud category

The standard deviation of the effective pressure for cloud layer A is given by

$$
\begin{aligned}
s_A &= \left[\left(\sum_{S_i}\omega_i f_A^i \left(\bar{p}_A^i\right)^2\right)\middle/\left(\sum_{S_i}\omega_i f_a^i\right) - (\bar{p}_A)^2\right]^{\frac{1}{2}}\\[2mm]
&= \left[\frac{\left[\begin{array}{c}(.20)(1)(620)^2+(.20)(2/3)(638)^2+(.15)(1)(664)^2\\+(.10)(1)(658)^2+(.02)(1)(612)^2\end{array}\right]}{(.20)(1)+(.20)(2/3)+(.15)(1)+(.10)(1)+(.02)(1)} - (640.95)^2\right]^{\frac{1}{2}}\\[2mm]
&= 18.85
\end{aligned}
\qquad (34)
$$

and for layer B

$$
\begin{aligned}
S_B &= \left[\frac{\left[\begin{array}{c}(.03)(1/2)(280)^2+(.10)(1)(290)^2+(.15)(1)(335)^2\\(.20)(1)(340)^2+(.20)(1)(333.33)^2+(.15)(1)(350)^2\end{array}\right]}{(.03)(1/2)+(.10)(1)+(.15)(1)+(.20)(1)+(.20)(1)+(.15)(1)} - (332.04)^2\right]^{\frac{1}{2}}\\[2mm]
&= 18.54
\end{aligned}
\qquad (35)
$$

SSF-104: Overlap condition weighted area percentage

The 11 cloud overlap conditions are given in Table 5. However, since we only allow 2 cloud layers in a footprint, only 4 of the 11 overlap conditions are possible for a given footprint. First we determine the two height categories from the mean effective pressures (SSF-86). Recall that the pressure for layer A is 640.95 so that it is category 2 (lower middle cloud) and layer B pressure is 332.04 and is in category 3 (upper middle cloud). Thus, the 4 possible cloud overlap conditions are 1, 3, 4, 9 (see Table 5). The area fractions are from (7) where q = clr, A/O, B/O, B/

A for clear, layer A only, layer B only, layer B over layer A, respectively, and where f_q^i are determined in the normal way and recorded in Table 4

$$C_{clr} = \text{clear area coverage} = \left(\sum_{S_i} \omega_i f_{clr}^i \right) \bigg/ \left(\sum_{S_i} \omega_i \right) \tag{36}$$

$$= [(.02)(1)+(.03)(1/2)]/0.97=0.036 \ (4\%)$$

$$C_{A/O} = \text{lower middle cloud only area coverage} = \left(\sum_{S_i} \omega_i f_{A/O}^i \right) \bigg/ \left(\sum_{S_i} \omega_i \right) \tag{37}$$

$$= [(.10)(1)+(.02)(1)]/0.97=0.123 \ (12\%)$$

$$C_{B/O} = \textit{upper} \text{ middle cloud only area coverage} = \left(\sum_{S_i} \omega_i f_{B/O}^i \right) \bigg/ \left(\sum_{S_i} \omega_i \right) \tag{38}$$

$$= [(.03)(1/2)+(.10)(1)+(.15)(1)+(.20)(1/3)]/0.97=0.341 \ (34\%)$$

$$C_{B/A} = \textit{upper} \text{ over lower middle cloud area coverage} = \left(\sum_{S_i} \omega_i f_{B/A}^i \right) \bigg/ \left(\sum_{S_i} \omega_i \right) \tag{39}$$

$$= [(.20)(1)+(.20)(2/3)+(.15)(1)]/0.97=0.498 \ (50\%)$$

SSF-106: Clear area percent coverage at imager resolution

Same as C_{clr} for SSF-104.

SSF-107: Overcast cloud area percent coverage at imager resolution

$$C_{ov} = \left(\sum_{S_i} \omega_i f_{ov}^i \right) \bigg/ \left(\sum_{S_i} \omega_i \right) \tag{40}$$

$$= [(.20)(1)+(.20)(2/3)]/0.97=0.343 \ (34\%)$$

SSF-108: Mean of imager radiances over clear area

$$\bar{I}_{clr} = \text{mean imager radiance over clear area} = \left(\sum_{S_i} \omega_i f_{clr}^i I_{clr}^i \right) \bigg/ \left(\sum_{S_i} \omega_i f_{clr}^i \right) \tag{41}$$

$$= \frac{(.02)(1)(12)+(.03)(1/2)(12)}{(.02)(1)+(.03)(1/2)} = 12.00$$

SSF-109: Stddev of imager radiances over clear area

$$S_{clr} = \left[\frac{(.02)(1)(12)^2 + (.03)(1/2)(12)^2}{(.02)(1) + (.03)(1/2)} - (12)^2 \right]^{\frac{1}{2}} = 0.00 \tag{42}$$

SSF-110: Mean of imager radiances over overcast cloud area

$$\bar{I}_{ov} = \text{mean imager radiance over overcast cloud area} = \left(\sum_{S_i} \omega_i f_{ov}^i I_{ov}^i \right) \Big/ \left(\sum_{S_i} \omega_i f_{ov}^i \right)$$

$$= \frac{(.20)(1)(40) + (.20)(2/3)(38)}{(.20)(1) + (.20)(2/3)} = 39.20 \tag{43}$$

SSF-111: Stddev of imager radiances over overcast cloud area

$$S_{ov} = \left[\frac{(.20)(1)(40)^2 + (.20)(2/3)(38)^2}{(.20)(1) + (.20)(2/3)} - (39.20)^2 \right]^{\frac{1}{2}} = 0.98 \tag{44}$$

SSF-112: Mean of imager radiances over full CERES FOV

$$\bar{I} = \text{mean imager radiance over FOV} = \left(\sum_{S_i} \omega_i I^i \right) \Big/ \left(\sum_{S_i} \omega_i \right)$$

$$= \frac{\left[\begin{array}{c} (.02)(12) + (.03)(13) + (.10)(29) + (.15)(28.30) + (.20)(40) \\ + (.20)(36) + (.15)(34) + (.10)(21) + (.02)(17) \end{array} \right]}{.02 + .03 + .10 + .15 + .20 + .20 + .15 + .10 + .02} = 31.46 \tag{45}$$

SSF-113: Stddev of imager radiances over full CERES FOV

$$\bar{S} = \left[\frac{\left[\begin{array}{c} (.02)(12)^2 + (.03)(13)^2 + (.10)(29)^2 + (.15)(28.30)^2 \\ + (.20)(40)^2 + (.20)(36)^2 + (.15)(34)^2 + (.10)(21)^2 + (.02)(17)^2 \end{array} \right]}{.02 + .03 + .10 + .15 + .20 + .20 + .15 + .10 + .02} - (31.46)^2 \right]^{\frac{1}{2}} \tag{46}$$

$$= 7.50$$

SSF-114: 5th percentile of imager radiances over full CERES FOV

We have 9 bins with mean radiances. The ordered radiances are

$$[\ 12,\ 13,\ 17,\ 21,\ 28.30,\ 29,\ 34,\ 36,\ 40\ ] \tag{47}$$

and their corresponding percentiles are

$$[\ 0,\ 12.5,\ 25,\ 37.5,\ 50,\ 62.5,\ 75,\ 87.5,\ 100] \tag{48}$$

The closest percentile to 5% is 0% with a radiance of 12.

SSF-115: 95th percentile of imager radiances over full CERES FOV

From SSF-114 above we see that the closest percentile to 95% is 100% with a radiance of 40.

SSF-116: Mean of imager radiances over cloud layer 1 (no overlap)

$$\bar{I}_{A/O} = \text{ mean imager radiance over cloud layer A } = \left(\sum_{S_i} \omega_i f^i_{A/O} I^i \right) \Big/ \left(\sum_{S_i} \omega_i f^i_{A/O} \right)$$
$$= \frac{(.10)(1)(21)+(.02)(1)(17)}{(.10)(1)+(.02)(1)} = 20.33 \tag{49}$$

SSF-117: Stddev of imager radiances over cloud layer 1 (no overlap)

$$S_{A/O} = \left[\frac{(.10)(1)(21)^2+(.02)(1)(17)^2}{(.10)(1)+(.02)(1)} - (20.33)^2 \right]^{\frac{1}{2}} = 1.54 \tag{50}$$

SSF-118: Mean of imager radiances over cloud layer 2 (no overlap)

$$\bar{I}_{B/O} = \text{ mean imager radiance over cloud layer B } = \left(\sum_{S_i} \omega_i f^i_{B/O} I^i \right) \Big/ \left(\sum_{S_i} \omega_i f^i_{B/O} \right)$$
$$= \frac{(.03)(1/2)(13)+(.10)(1)(29)+(.15)(1)(28.30)+(.20)(1/3)(36)}{(.03)(1/2)+(.10)(1)+(.15)(1)+(.20)(1/3)} = 29.37 \tag{51}$$

SSF-119: Stddev of imager radiances over cloud layer 2 (no overlap)

$$S_{B/O} = \left[\frac{(.03)(1/2)(13)^2+(.10)(1)(29)^2+(.15)(1)(28.30)^2+(.20)(1/3)(36)^2}{(.03)(1/2)+(.10)(1)+(.15)(1)+(.20)(1/3)} - (29.37)^2 \right]^{\frac{1}{2}} \tag{52}$$
$$= 4.62$$

SSF-120: Mean of imager radiances over cloud layer 1 and 2 overlap

$$\grave{I}_{B/A} = \text{mean imager radiance over cloud layer overlap} = \left(\sum_{S_i} \omega_i f_{B/A}^i I^i \right) \Big/ \left(\sum_{S_i} \omega_i f_{B/A}^i \right) \tag{53}$$

$$= \frac{(.20)(1)(40)+(.20)(2/3)(36)+(.15)(1)(34)}{(.20)(1)+(.20)(2/3)+(.15)(1)} = 37.03$$

SSF-121: Stddev of imager radiances over cloud layer 1 and 2 overlap

$$S_{B/A} = \left[\frac{(.20)(1)(40)^2+(.20)(2/3)(36)^2+(.15)(1)(34)^2}{(.20)(1)+(.20)(2/3)+(.15)(1)} - (37.03)^2 \right]^{\frac{1}{2}} = 2.67 \tag{54}$$

Table 1. Imager Pixel Parameters

General	Cloud layer 1 (low)	Cloud layer 2 (high)

1. Number of cloud layers (-1, 0, 1, or 2)
2. Cloud fraction (0-1.0)
3. Time of imager observation
4. Imager colatitude and longitude
5. Altitude of surface above sea level
6. Surface type index
7. Imager viewing zenith angle
8. Imager relative azimuth angle
9. Imager channel identifier (delete??)
10. Imager radiance for #9 (20 items)
11. Sunglint index
12. Snow/Ice index
13. Aerosol index
14. Fire index
15. Shadowed index
16. Total aerosol vis. optical depth, clear
17. Total aerosol effective radius, clear
18. Imager-based surface skin temperature
19. Algorithm notes
	20. Visible optical depth
	21. Infrared emissivity
	22. Water/Ice path
	23. Top pressure
	24. Effective* pressure
	25. Effective temperature
	26. Effective height
	27. base pressure
	28. Particle radius/diameter
	29. Particle phase
	    (0-ice or 1-water)
	30. Vertical Aspect ratio
		31. Visible optical depth
		32. Infrared emissivity
		33. Water/Ice path
		34. Top pressure
		35. Effective* pressure
		36. Effective temperature
		37. Effective height
		38. base pressure
		39. Particle radius/diameter
		40. Particle phase
		    (0-ice or 1-water)
		41. Vertical Aspect ratio

* Effective as viewed from space or cloud top if optically thick and cloud center if optically thin.

Table 2:

Bin Index	1	2	3	4	5	6	7	8	9	10	i
Pixel Data											
No. of layers	0	1	1	1	1	1	1	0	*	0	#1 Tab4.4-3
Subgrid mask	-	1/16	13/16	15/16	16/16	16/16, 16/16, 14/16	14/16	-		-	#2
Imager rad.	12	14	29	*	40	*, 38, 32	34	21		17	#11 1st item
General parm	-	x_{22}	*	x_4	x_5	x_{16}, x_{26}, x_{36}	x_7	-		-	#21,22,…,etc
Calculated Quantities											
PSF weight	.02	.03	.10	.15	.20	.20	.15	.10	.03	.02	ω_i
No. pixels	1	2	1	1	1	3	1	1	0	1	n^i
Clear fraction	1	1/2	0	0	0	0	0	1		1	f^i_{clr}
Broken frac	0	1/2	1	1	0	1/3	1	0		0	f^i_{bk}
Overcast frac	0	0	0	0	1	2/3	0	0		0	f^i_{ov}
Cloud frac	0/16	1/32	13/16	15/16	16/16	46/48	14/16	0/16		0/16	f^i_{cld}
Clear radiance	12	12	-	-	-	-	-	21		17	I^i_{clr}
Broken rad	-	14	29	31.19#	-	32	34	-		-	I^i_{bk}
Overcast rad	-	-	-	-	40	38	-	-		-	I^i_{ov}
Mean radiance	12	13	29	31.19#	40	36	34	21		17	$\bar{I}^i$
Mean parm	-	$x_2=x_{22}$	*	x_4	x_5	$x_6=(x_{16}+x_{26}+x_{36})/3$	x_7	-	-	-	$\bar{x}^i$

* No data, # data fill, - N/A

Table 3:

Bin Index	1	2	3	4	5	6	7	8	9	10	i
Pixel Data											
No. of layers	0	1	1	1	1	1	1	0	*	0	#1 Tab4.4-3
Subgrid mask	-	1/16	13/16	15/16	16/16	16/16, 16/16, 14/16	14/16	-		-	#2
Imager rad.	12	14	29	*	40	*, 38, 32	34	21		17	#11 1st item
General parm	-	x_{22}	*	x_4	x_5	x_{16}, x_{26}, x_{36}	x_7	-		-	#21,22,....etc
Eff. Pressure layer 1(low)	-	250	320	245	268	290, 330, 340	335	-		-	#25
Calculated Quantities											
PSF weight	.02	.03	.10	.15	.20	.20	.15	.10	.03	.02	ω_i
No. pixels	1	2	1	1	1	3	1	1	0	1	n^i
Clear fraction	1	1/2	0	0	0	0	0	1		1	f^i_{clr}
Broken frac	0	1/2	1	1	0	1/3	1	0		0	f^i_{bk}
Overcast frac	0	0	0	0	1	2/3	0	0		0	f^i_{ov}
Cloud frac	0/16	1/32	13/16	15/16	16/16	46/48	14/16	0/16		0/16	f^i_{cld}
Clear radiance	12	12	-	-	-	-	-	21		17	$\bar{I}^i_{clr}$
Broken rad	-	14	29	31.19#	-	32	34	-		-	$\bar{I}^i_{bk}$
Overcast rad	-	-	-	-	40	38	-	-		-	$\bar{I}^i_{ov}$
Mean radiance	12	13	29	31.19#	40	36	34	21		17	$\bar{I}^i$
Mean parm	-	$x_2=x_{22}$	*	x_4	x_5	$x_6=(x_{16}+x_{26}+x_{36})/3$	x_7	-		-	$\bar{x}^i$
clear fraction	1	1/2	0	0	0	0	0	1		1	
1-layer fraction	0	1/2	1	1	1	1	1	0		0	
Mean Pressure layer 1(low)	-	250	320	245	268	320	335	-		-	
Cld Category layer A(low)	-	-	320	-	-	320	335	-		-	
layer B(high)	-	250	-	245	268	-	-	-		-	

60

* No data, # data fill, - N/A

Table 4:

Bin Index	1	2	3	4	5	6	7	8	9	10	i
Pixel Data											
No. of layers	0	1	1	1	2	2, 2, 2	2	2	*	1	#1 Tab4.4-3
Subgrid mask	0/16	1/16	13/16	15/16	16/16	16/16, 16/16, 14/16	14/16	9/16		3/16	#2
Imager rad.	12	14	29	*	40	*, 38, 32	34	21		17	#11 1st item
General parm	-	x_2, -	*	x_4	x_5, y_5	x_{16},y_{16}, x_{26},y_{26}, x_{36},y_{36}	x_7, y_7	x_8, y_8		x_{10}, -	#21,22,...,etc ; #32,33,...,etc
Eff. Pressure layer 1(low)	-	280	290	335	620	330, 638, *	664	710		612	#25
Eff. Pressure layer 2(high)	-	-	-	-	340	-, 325, 345	350	606		-	#36
Calculated Quantities											
PSF weight	.02	.03	.10	.15	.20	.20	.15	.10	.03	.02	ω_i
No. pixels	1	2	1	1	1	3	1	1	0	1	n^i
Clear fraction	1	1/2	0	0	0	0	0	0		0	f^i_{clr}
Broken frac	0	1/2	1	1	0	1/3	1	1		1	f^i_{bk}
Overcast frac	0	0	0	0	1	2/3	0	0		0	f^i_{ov}
Cloud frac	0/16	1/32	13/16	15/16	16/16	46/48	14/16	9/16		3/16	f^i_{cld}
Clear radiance	12	12	-	-	-	-	-	-		-	I^i_{clr}
Broken rad	-	14	29	28.30#	-	32	34	21		17	I^i_{bk}
Overcast rad	-	-	-	-	40	38	-	-		-	I^i_{ov}
Mean radiance	12	13	29	28.30#	40	36	34	21		17	I^i
Mean parm	-	$x_2 = x_{22}$	*	x_4	x_5	$x_6 = (x_{16} + x_{26} + x_{36})/3$	x_7	-		-	$\bar{x}^i$
Mean Pressure layer 1(low)	-	280	290	335	620	638	664	710		612	$\bar{p}_A$
Mean Pressure layer 2(high)	-	-	-	-	340	335	350	606		-	$\bar{p}_B$
Layer Pressure layer A(low)	-	-	-	-	620	638.33	664	658		612	
Layer Pressure layer B(high)	-	280	290	335	340	333.33	350	-		-	
Clear fraction	1	1/2	0	0	0	0	0	0		0	f^i_{clr}
Layer A(low) frac	0	0	0	0	1	2/3	1	1		1	f^i_A
Layer B(high) frac	0	1/2	1	1	1	1	1	0		0	f^i_B
Overlap fractions Clear frac	1	1/2	0	0	0	0	0	0		0	f^i_{clr}
Layer A only	0	0	0	0	0	0	0	1		1	$f^i_{A/O}$
Layer B only	0	1/2	1	1	0	1/3	0	0		0	$f^i_{B/O}$
Layer B over A	0	0	0	0	1	2/3	1	0		0	$f^i_{B/A}$

Table 4.4-5

Index	Definition	Symbol	
No layer			
1	clear (no clouds)	CLR	0
One layer			
2	low cloud only (cloud effective pressure > 700 hPa)	L	1
3	lower middle cloud only (700 ≥ eff. pressure > 500 hPa)	LM	2
4	upper middle cloud only (500 ≥ eff. pressure > 300 hPa)	UM	3
5	high cloud only (eff. pressure ≤ 300 hPa)	H	4
Two layers			
6	high cloud over upper middle cloud	H/UM	43
7	high cloud over lower middle cloud	H/LM	42
8	high cloud over low cloud	H/L	41
9	upper middle cloud over lower middle cloud	UM/LM	32
10	upper middle cloud over low cloud	UM/L	31
11	lower middle cloud over low cloud	LM/L	21

CERES footprint

2 km

Imager pixel

top view

side view

**4 Cloud
Height Categories**

4. high clouds

300 hPa

layer 2

Category B

3. upper middle clouds

500 hPa

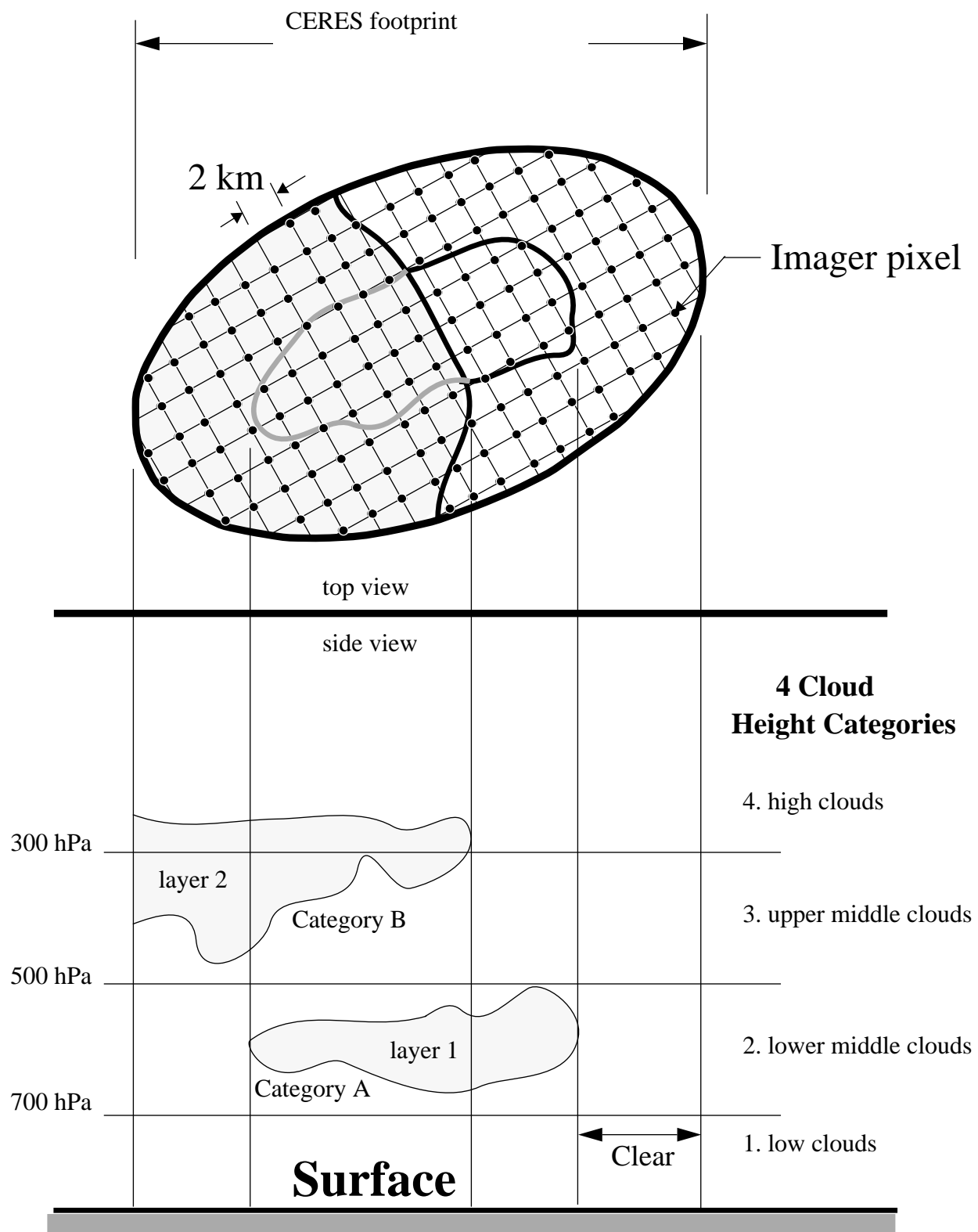layer 1

2. lower middle clouds

Category A

700 hPa

Clear

1. low clouds

Surface

Figure 1. CERES Cloud Geometry